



# ***SUMMARY OF RESEARCH 1996***

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Monterey, CA 93943-5000

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**NAVAL POSTGRADUATE SCHOOL**  
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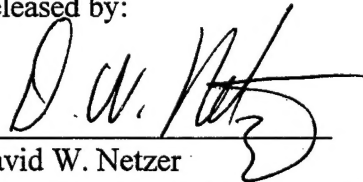
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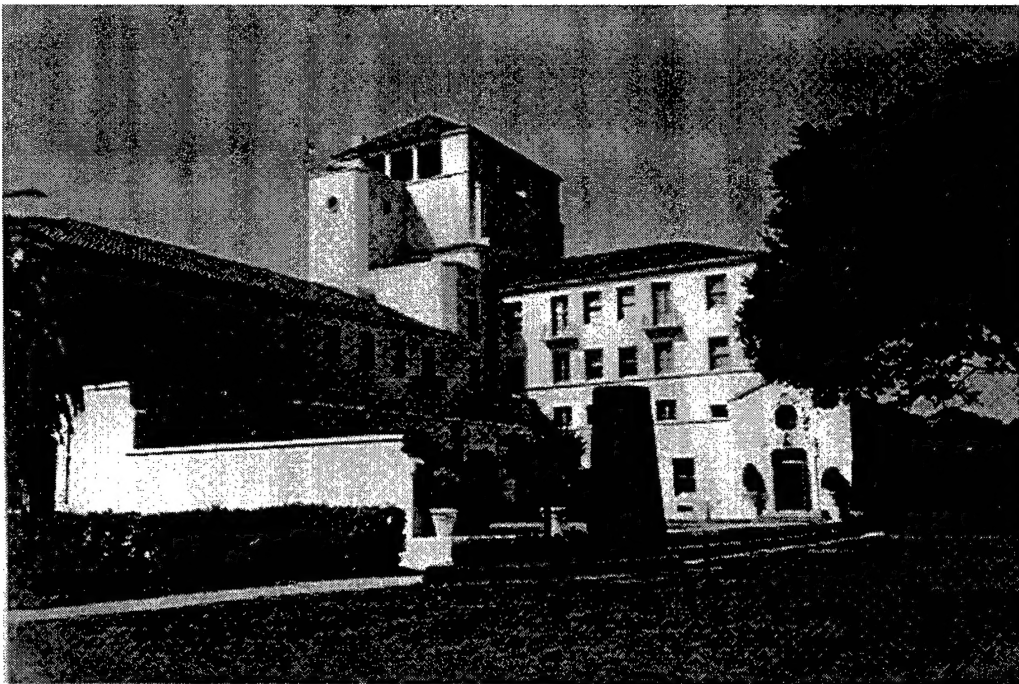
**DEPARTMENT OF  
PHYSICS**

**ANTHONY ATCHLEY**  
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## **THE NAVAL POSTGRADUATE SCHOOL MISSION**

The mission of the Naval Postgraduate School is to increase the combat effectiveness of US and Allied armed forces and enhance the security of the USA through advanced education and research programs focused on the technical, analytical, and managerial tools needed to confront defense-related challenges.



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## Preface

Research is an integral part of graduate education. At the Naval Postgraduate School (NPS), the goals of research are to:

- Provide a meaningful, high quality, capstone learning experience for our students.
- Keep faculty on the leading edge of advances in defense-related science, technology, management and policy to ensure that the latest information is incorporated into NPS courses and curricula.
- Apply faculty and student knowledge to enhance DoN/DoD operational effectiveness.

Pursuit of these goals increases the technical and managerial capability of the officer corps to keep pace with an increasingly complex defense posture in today's world.

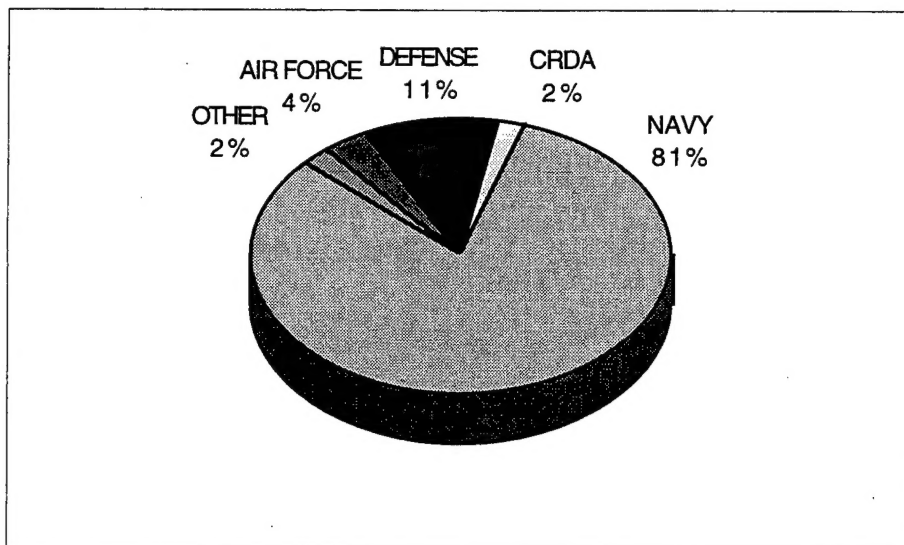
New technologies and policy changes will of course occur, necessitating changes in educational programs and stronger ties between the fleet and the support establishment. NPS must remain poised to face this challenge and to utilize emerging technologies and new policies within its curricula programs. Faculty, therefore, must stay abreast of these developments through a dynamic research program that helps fulfill the School's goals of excellence, uniqueness, and relevance.

The overall research program at NPS has three funded components. The Direct Funded Research and Institute for Joint Warfare Analysis Programs are institutionally funded within the School's operating budget. The Direct Funded Research Program is administered by the Associate Provost and Dean of Research. The Institute for Joint Warfare Analysis Program is administered by the Director of IJWA.

- The Direct Funded Research (DFR) Program provides funding to stimulate innovative research ideas of benefit to the DoN and may be used for cost-sharing with reimbursable research efforts. This funding ensures, in particular, that all Navy-sponsored NPS curricula are equitably supported, that new faculty are provided an opportunity to establish a research program of importance to DoN/DoD and other national security interests, and that faculty and students from across the campus are encouraged to interact with one another.
- The Institute for Joint Warfare Analysis Research Program provides funding to stimulate innovative research ideas with a strong emphasis on joint, interdisciplinary areas. This funding ensures that joint relevance is a consideration of faculty research.
- The Reimbursable Research (RR) Program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policy makers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. This ensures that NPS research remains highly regarded by academic peers and government officials and fosters a closer relationship between NPS and other outside organizations.

The three research programs are complementary and ensure that the overall research program is flexible, responsive, balanced and supportive of the unique needs of the military.

In 1996, the level of the research effort at the Naval Postgraduate School was 141 faculty workyears and exceeded 29 million dollars. Eighty percent of the research was funded by reimbursable sponsors and 20 percent was funded by the Naval Postgraduate School. Sixty-five percent of the work was performed for the Navy and the remainder was sponsored by other agencies, both DoD and non-DoD. A profile of the reimbursable program of the Department of Physics is provided in Figure 1:



Size of Program: \$1,534K

Figure 1. Department of Physics - Sponsor Profile

Research at NPS is carried out by faculty in the School's eleven Academic Departments, four Interdisciplinary Groups and the School of Aviation Safety. In the pages that follow, research summaries are provided for projects undertaken by faculty in the Department of Physics during 1996. An overview and faculty listing are provided as an introduction. A list of publications is also included, if applicable. Abstracts for thesis advised by department faculty in 1996 complete this research summary.

Questions about particular projects may be directed to the Faculty Principal Investigator listed, the Department/Group Chair, or the Department Associate Chair for Research. Questions may also be directed to the Research Office. General questions about the NPS Research Program should be directed to the Research Office at (408) 656-2098 (voice) or [research@nps.navy.mil](mailto:research@nps.navy.mil) (e-mail).

August 1997

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## DEPARTMENT SUMMARY

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During CY 1996, 17 Physics Department faculty members participated in approximately 38 different research projects. Although the scope of these projects is quite broad, the research in the Physics Department can be grouped, for the purposes of this summary, into seven general areas: 1) Electromagnetic Radiation and Propagation Phenomena, 2) Remote Sensing, 3) Weapons/Shipboard Systems Technologies, 4) Ocean Acoustics and Air/Sea Interactions 5) Combat Systems Technology and Policy, 6) Mine Warfare, and 7) Solid State Physics and Fundamental Processes. An overview of research activities in each of these areas follows.

### Electromagnetic Radiation and Propagation Phenomena

Donald Walters is continuing work on atmospheric optical turbulence in support of the US Air Force Airborne Laser Program. A single temperature probe microthermal balloon system was developed and deployed 20-25 August 1996, at White Sands Missile Range, NM, in conjunction with a Joint Army, Air Force and Navy field experiment that included the ARGUS KC135 instrumented aircraft and the US Army 50 Mhz stratospheric radar. The NPS system achieved 500 uK rms noise at a 320 Hz sample rate that translates into 3-cm vertical temperature resolution in the stratosphere. In addition, ten years of atmospheric coherence length and isoplanatic angle measurements were collated and compared, with an emphasis on enumerating the statistical characteristics of the data. Understanding the atmospheric turbulence parameters is a key part determining the viability of optical communication systems for multi-gigabit communication links.

Scott Davis is continuing a multi-year project which has as its primary goal the development of a proof-of-concept prototype instrument capable of recording fully multiplexed images and multispectral images at long infrared wavelengths, where efficient focal plane array technology is not available. The primary research tasks carried out during the past year were the second-phase design of the electromechanical servo systems that will perform the precise control functions within the prototype instrument. Key electronic circuits were designed, calculations for determining minimum acceptable drive characteristics for the servomotors were completed, motor specifications were determined, and the servomotors were procured. In addition, several software modules for the processing of multiplexed image data were written, and more detailed optical designs of portions of the optical system's layout were conducted.

William Colson continued to work in the area of free electron laser (FEL) simulations. His involvement included investigation of wavelength modulation and limit cycle behavior in FELs, atmospheric propagation simulations of high average power FELs, and ultraviolet FELs. He served as a member of the International Executive Subcommittee on Commentary on the National Academy of Science's National Research Council Committee on FELs and Other Advanced Coherent Light Sources, a member of the DOE Review Panel for the CEBAF/LPC Laser Processing Project, and chair of the Defense Applications Working Group for the CEBAF Laser Processing Consortium.

Alf Cooper is continuing work in a number of areas related to the application of infrared technology to the Navy in support of NAVSEA and NCCOSC. One project involves the development of a split-field LWIR polarimeter. Another involves analysis of IR ship signatures from the PREOS92 experiment.

### Remote Sensing

David Cleary and Chris Olsen are working in the area of hyperspectral remote sensing. Professor Cleary is conducting experiment work this field. He is in the process of building an ultraviolet hyperspectral imager and a hyperspectral polarimeter. Professor Olsen is working on the phenomenology and algorithm development of hyperspectral imaging. His concentration is on littoral and near-shore environments.

Robert Harney is developing laser and lidar technologies. During 1996 a laser/lidar laboratory was established. The general design of the cw Doppler lidar was completed and all essential components (laser, detector, acousto-optic modulator, optics, and rf electronics) were procured. Assembly of both the lidar optical subsystem and the processing



## **DEPARTMENT SUMMARY**

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electronics was begun and was 50% complete by the end of 1996. In addition, a vibration calibration target consisting of a retroreflector mounted on a piezoelectric actuator and driven by an audio frequency signal was fabricated and its predicted amplitude vs. voltage and frequency response was verified. A high-efficiency, short-pulse, high-prf green laser that is nearly ideal for short-range aerosol profiling was identified and a sample procured. Design of a scanning optical system and photon-counting processing electronics was begun. Procurement of additional components is expected to begin in February 1997. Conceptual design of wavelength-tunable and ultraviolet laser sources as upgrades to this aerosol-profiling lidar was also begun.

### **Weapons/Shipboard Systems Technologies**

Steve Baker is also working to develop and validate through laboratory and field measurements a numerical computer model of the PHALANX gun which can be used to quantify the effects of design changes and/or modifications on its performance. Forced harmonic vibration measurements on a PHALANX gun subassembly were performed in the laboratory. Measurements were made with and without the production muzzle restraint installed. Modal parameters (frequency, amplitude, mode shape) were obtained. These were used to validate and to improve the finite-element model of the PHALANX. A comparison was made between the computed and measured modal parameters. Good agreement was obtained. Including the muzzle restraint, it was not possible to obtain good agreement between experimental and finite-element results for modal parameters. It is suspected that this is due to "play" in the actual muzzle restraint mounting system, which is not modeled in the finite-element model.

Robert Keolian is exploring how the physics of a mechanical structure influences the choice of a noise cancellation technique, in support of the design of the Conformal Array of Velocity Sensors (CAVES) fiber optic flank array on the hull of the New Attack Submarine. Vibration measurements were made at multiple locations on the USS Hartford (SSN 768) while in transit at various depths and speeds. The goal has been to predict the vibration waveform at a hull location from knowledge of the vibrations at the internal sources. Various adaptive and non-adaptive filters were used to predict the output from the input driving signal. While investigating the non-parametric methods of system identification, they found an apparently new way to improve the empirical transfer function estimate (ETFE).

Anthony Atchley, Thomas Hofler, and Robert Keolian are working in this area of thermoacoustics. Thermoacoustics is an emerging technology that represents a feasible, non-CFC, non-global warmer cooling alternative. There were three main areas of effort during 1996. The first involved testing new stack geometries, including pin stacks, stacked screens, and reticulated vitreous carbon (RVC) stacks. Each of these showed significant improvement in performance over parallel plate stacks. The latter two have the added advantage of near-trivial fabrication. Lessons learned from this work were incorporated into the design of the 500 W heat driven cooler. This device, based on a novel design, is within weeks of testing. It will serve as a prototype for shipboard applications. The final area of research is the measurement of the temperature evolution in a parallel plate stack. The purpose of this project is to provide data on simple devices for comparison to time-dependent nonlinear models of thermoacoustics.

Robert Harney is working to integrate the electromagnetic engineering (EMENG) suite of tools and top-side design principles being developed by the Combat Systems Design and Engineering Group (03K) of NAVSEA into NPS's Total Ship Systems Engineering program. The intent is to educate the TSSE students concerning the need and techniques for improving the electromagnetic characteristics and performance of a surface combatant, and to serve as a beta test site for proving out the evolving EMENG suite of computer-aided design tools.

### **Ocean Acoustics and Air/Sea Interactions**

Kevin Smith worked on several projects concerning ocean acoustic propagation. The goal of one project was to upgrade an advanced acoustic propagation model for use with current and future research endeavors and to acquire a computer workstation capable of the CPU- and memory-intensive processing anticipated. A second project is to de-



## DEPARTMENT SUMMARY

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velop a theory on the effects of ocean mesoscale perturbations on adiabatic mode travel times. Confirmation of the theory will be in the form of numerical predictions obtained by a broadband, range-dependent parabolic equation model from which the field can be decomposed into local normal modes. The modeled ocean environment will be composed of a superposition of Rossby waves providing realistic mesoscale ocean features. The objective of a third project was to enhance understanding of the physics of long-range bottom reverberation in the context of low-frequency, active, underwater acoustics and successfully predict with numerical models the effects on current sonar systems. Another project involved work to understand the limits of signal resolution imposed by complex forward-propagating multipaths. The objective of another project is to study the physics and predictability of 3-D, broadband acoustic propagation upslope onto the continental shelf in the presence of strong oceanographic frontal features, specifically in the vicinity of the mid-Atlantic Bight. Finally, he was involved with a study of the influence of the physics mismatch due to less-than-ideal acoustic ray model predictions on the localization of full-wave signals and to coordinate future research efforts towards a system demonstration of passive transient localization.

Donald Spiel is continuing a research project involved determining the ocean's aerosol source function, that is, to determine how many aerosols per unit time per unit area are generated by oceanic processes. In the past year the effort to determine the birth of jet drops over the range of bubble sizes 350 to 1500  $\mu\text{m}$  radius was completed. The ejection speeds, time of ejection and the height at which all the jet droplets broke off the ascending jet measured. Previously, the size distributions of these drops were determined. In addition, a theoretical solution to the problem of the number of film drops as a function of bubble size was advanced. Experiments were begun to test the efficacy of this theory.

### Combat Systems Technology and Policy

Gordon Schacher is working on modeling and simulation for combat systems in support of Theater Air Defense, NAVSEA. In addition, he is developing a process by which chemical/biological hazard assessment models/simulations could be evaluated.

Xavier Maruyama participated in activities associated with the Institute for Joint Warfare Analysis. The project investigated available and potential technologies related to Technologies for Operations Other than War (TOOTW), including Less-than-Lethal Weapons, Landmines, Defensive Technologies, Situational Awareness Technologies, and Training and Simulation Issues.

### Mine Warfare

Donald Walters continued research on mine detection and identification. His research concentrates on investigating and demonstrating the feasibility of high resolution imaging sonars for mine classification and identification. He is also investigating the possibility of using adaptive optics techniques to improve the image quality of high resolution sonars.

### Solid State Physics and Fundamental Processes

James Luscombe is involved with a project to advance the state of the art in quantum device modeling. He is developing a wide variety of models for electrons in semiconductor nanostructures and associated issues related to the ultimate scaling of electronic devices. In addition, he is developing models of the self-consistent electrostatic potential in quantum dot nanostructures as well as solutions to the Schrödinger equation in quantum wire geometries. He is also working develop models of the time-dependent, nonequilibrium elastic scattering structure factor for the investigation of strongly nonequilibrium processes in adsorbed surface overlayers.

## DEPARTMENT SUMMARY

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Andrés Larraza is establishing basic experimental and theoretical research in nonlinear waves. Two areas of research were covered: Absorption of sound by noise with possible applications to the excess attenuation in a shallow water environment, and AM-FM conversion with applications to tunable lasers and high data rate fiber optic communications.

The Physics Department maintains and a linear electron accelerator (linac) and a flash x-ray machine. The facilities are used for classroom and research use especially by the Physics and ECE Departments. The principal investigator for these facilities is Professor Xavier Maruyama. He collaborated on a research project that studied the radiation effects on electronics, and investigation of parametric x-radiation.

## PROJECT SUMMARIES

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### BASIC RESEARCH IN THERMOACOUSTIC HEAT TRANSPORT

A.A. Atchley, Professor

T.J. Hofler, Research Associate Professor

R.M. Keolian, Associate Professor

Department of Physics

Sponsor: Office of Naval Research

**OBJECTIVE:** Thermoacoustics is an emerging cooling technology that is completely CFC free and offers the potential for high reliability. The objectives of this research are to: 1) investigate mechanisms that place fundamental limitations on the high amplitude performance of thermoacoustic engines, and 2) pursue shipboard applications of thermoacoustics. Specific tasks include the design and construction of a heat driven refrigerator capable of 500 W of cooling power, the investigation of new stack and engine geometries, and measurement of fundamental thermoacoustic processes.

**SUMMARY:** There were three main areas of effort during 1995. The first involved testing new stack geometries, including pin stacks, stacked screens, and reticulated vitreous carbon (RVC) stacks. Each of these showed significant improvement in performance over parallel plate stacks. The latter two have the added advantage of near-trivial fabrication. Lessons learned from this work were incorporated into the design of the 500 W heat driven cooler. This device, based on a novel design, is within weeks of testing. It will serve as a prototype for shipboard applications. The final area of research is the measurement of the temperature evolution in a parallel plate stack. The purpose of this project is to provide data on simple devices for comparison to time-dependent nonlinear models of thermoacoustics.

#### PUBLICATIONS:

Adeff, J.A., Hofler, T.J., Atchley, A.A., and Moss, W.C., "Measurements with Reticulated Vitreous Carbon Stacks in Thermoacoustic Prime Movers and Refrigerators," 132nd Meeting of the Acoustical Society of America, Honolulu, HI, Journal of the Acoustical Society of America, 100, No. 4, Pt. 2, 2845(A), 1996.

Atchley, A.A., Hebert, D.D., Lin, H.T., Meng, C.K., and Salindong, A.R., "Measurements of Transient Effects in Thermoacoustics," 131st Meeting of the Acoustical Society of America, Indianapolis, IN, Journal of the Acoustical Society of America, 99, No. 4, Pt. 2, 2559(A), 1996.

Gibson, R.J., Nessler, F.S., and Keolian, R.M., "Measurements of a Thermoacoustic Pin Stack," 132nd Meeting of the Acoustical Society of America, Honolulu, HI, Journal of the Acoustical Society of America, 100, No. 4, Pt. 2, 2845A, 1996.

Hofler, T.J., and Reed, M.S., "Measurements with Wire Mesh Stacks in Thermoacoustic Prime Movers," Journal of the Acoustical Society of America, Vol. 99, No. 4, Pt. 2, April 1996.

Hofler, T.J., Adeff, J.A., Heatter, T., and Atchley, A.A., "An Experimental Thermoacoustically Driven Thermoacoustic Refrigerator," 132nd Meeting of the Acoustical Society of America, Honolulu, HI, Journal of the Acoustical Society of America, 100, No. 4, Pt. 2, 2816(A), 1996.

Lin, H.T., and Atchley, A.A., "Investigation of a Toroidal Thermoacoustic Prime Mover" 132nd Meeting of the Acoustical Society of America, Honolulu, HI, Journal of the Acoustical Society of America, 100, No. 4, Pt. 2, 2846(A), 1996.

Salindong, A.R., Hebert, D.D., and Atchley, A.A., "Measurements of the Evolution of the Temperature Profile in a Parallel Plate Stack" 132nd Meeting of the Acoustical Society of America, Honolulu, HI, Journal of the Acoustical Society of America, 100, No. 4, Pt. 2, 2846(A), 1996.

## PROJECT SUMMARIES

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### CONFERENCE PRESENTATIONS:

Adeff, J.A., Hofler, T.J., Atchley, A.A., and Moss, W.C., "Measurements with Reticulated Vitreous Carbon Stacks in Thermoacoustic Prime Movers and Refrigerators," 132nd Meeting of the Acoustical Society of America, Honolulu, HI, December 1996.

Atchley, A.A., Hebert, D.D., Lin, H.T., Meng, C.K., and Salindong, A.R., "Measurements of Transient Effects in Thermoacoustics," 131st Meeting of the Acoustical Society of America, Indianapolis, IN, May 1996.

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Salindong, A.R., Hebert, D.D., and Atchley, A.A., "Measurements of the Evolution of the Temperature Profile in a Parallel Plate Stack," 132nd Meeting of the Acoustical Society of America, Honolulu, HI, December 1996.

### THESES DIRECTED:

Gibson, R.J., "An Experimental Comparison of a Pin Stack to a Conventional Stack in a Thermoacoustic Prime Mover," Master's Thesis, Naval Postgraduate School, June 1996.

Heatter, T.W., "Instrumentation and Measurement of a Thermoacoustically Driven Thermoacoustic Refrigerator," Master's Thesis, Naval Postgraduate School, December 1996.

Hebert, D.D., "Evolution of the Temperature Profile in a Simple Thermoacoustic Stack," Master's Thesis, Naval Postgraduate School, December 1996.

Meng, C.K., "Transient Phenomena in Thermoacoustic Prime Movers," Master's Thesis, Naval Postgraduate School, June 1996.

Reed, M.S., "Measurements with Wire Mesh Stacks in Thermoacoustic Prime Movers," Master's Thesis, Naval Postgraduate School, June 1996.

Salindong, A.R., "Evolution of the Temperature Profile in a Simple Thermoacoustic Stack," Masters Thesis in Engineering Acoustics and Physics, December 1996.

### OTHER:

Hofler, T.J., "A High-efficiency Heat-driven Acoustic Cooling Engine with No Moving Parts," Navy case #78062, submitted, October 1996.

**DoD KEY TECHNOLOGY AREAS:** Environmental Quality

**KEYWORDS:** Thermoacoustic, refrigeration, CFC

## PROJECT SUMMARIES

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### VIBRATION MEASUREMENTS IN SUPPORT OF THE ELECTRO-OPTICAL SENSOR UPGRADE TO THE PHALANX CLOSE-IN WEAPONS SYSTEM

Stephen R. Baker, Associate Professor

Department of Physics

Sponsor: Naval Surface Warfare Center-Dahlgren Division

**OBJECTIVES:** To perform vibration measurements on a prototype of the new PHALANX electro-optical sensor package during a live-fire exercise, and to analyze the acceleration data gathered and report whether or not the resulting vibration levels are compatible with design specifications.

**SUMMARY:** The Navy is considering adding an electro-optical (EO) sensor subsystem to the PHALANX Close-In Weapons System (CIWS). Design specifications require the servo-stabilized FLIR camera platform to have an rms angular displacement across the gun sight of no more than 100 microradians. NPS was tasked to perform vibration measurements on a prototype of the EO sensor subsystem mounted on a PHALANX gun radar dome during live-fire testing.

Professor Baker and student LT. James Schmidt obtained the vibration measurements during live-fire tests conducted at NSWC, Dahlgren, VA, on 30 July and 1 August 1996. A combination of uniaxial, triaxial, and angular accelerometers were mounted at eighteen locations on the EO stabilization system and the FLIR camera. Live-fire acceleration data were collected for eight different configurations of accelerometers using an 8-channel data analyzer. A sampling rate of 25600/sec was used. Each 7.2-sec acceleration time record (one per channel) is composed of 184320 samples. The calibration of each accelerometer and its analyzer channel electronics was checked in the lab at NPS. The accelerometer voltage time records stored by the analyzer were exported to ASCII files readable by MATLAB.

A spectral analysis of the data was performed for frequencies from 10 Hz to 10 kHz using MATLAB. Broad-band (20 Hz to 2 kHz) and narrow-band spectrum levels were computed for each measured acceleration component. Single-axis input linear acceleration values observed at the pedestal feet were approximately 4 to 7 grams. Single-axis linear acceleration values observed at the FLIR camera mount were approximately 1 gram. These values are consistent with design specifications. For unknown reasons, data taken with the angular accelerometers are faulty, and so were not used. Estimates of the broadband rms angular displacement of the FLIR camera mount from linear accelerometer measurements are 50 microradians in azimuth and 140 microradians in elevation. Estimates made from optical measurements made by others at the same time are approximately 30 microradians in each direction. The reason for the discrepancy remains unknown at this time. It is suggested that the optical measurements are more trustworthy, since they are more direct, and that the rms angular jitter at the FLIR camera mount meets design specifications.

#### THESIS DIRECTED:

Schmidt, J., "Vibration Measurements on the PHALANX Electro-Optical Stabilization System," Master's Thesis, Naval Postgraduate School, September 1996.

**DoD KEY TECHNOLOGY AREAS:** Other (Weapons)

**KEYWORDS:** PHALANX, Close-In Weapons System (CIWS), structural dynamics, vibration

### ALGORITHM DEVELOPMENT FOR AUTOMATIC TARGET RECOGNITION USING WAVELET TRANSFORMS

D.D. Cleary, Associate Professor

Department of Physics

Sponsor: U.S. Air Force

**OBJECTIVE:** The goal of this project was to develop a technique for detecting the spectral signature of sub-pixel targets using an appropriate wavelet transformation.

## PROJECT SUMMARIES

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**SUMMARY:** The motivation for this research was two-fold. First, there is a strong need for rapid computer algorithms that automatically detect targets in a hyperspectral imaging hypercube. Second, the compactness' feature of wavelet transforms could in principle be used to detect the spectral signature of a weak target against a bright background. It was demonstrated that under ideal circumstances this was indeed the case. Using synthetic data we were able to detect the presence of targets with pixel-fractions as low as 0.01. Unfortunately, this technique was found to be ineffective when realistic noise levels were added to the synthetic spectrum.

**THESES DIRECTED:**

Nikolaidis, D., "Detection of Mines Using Hyperspectral Analysis," Master's Thesis, Naval Postgraduate School, June 1996.

Collins, B.H., "Thermal Imagery Spectral Analysis," Master's Thesis, Naval Postgraduate School, June 1996.

**DoD KEY TECHNOLOGY AREAS:** Sensors

**KEYWORDS:** Hyperspectral imaging

### AN INVESTIGATION OF THE USE OF POLARIZATION WITH THE HYDICE HYPERSPECTRAL IMAGER

D.D. Cleary, Associate Professor

Department of Physics

Sponsor: Navy Tactical Exploitation of National Capabilities Office

**OBJECTIVE:** The objective of this project was to investigate the use of multispectral and hyperspectral polarization for automatic target recognition in satellite imaging systems. This is a new concept whereby the Stokes polarization parameters would be measured for every band of a multispectral imager or for every channel of a hyperspectral imager. Measurement of these parameters could greatly improve our automatic target recognition capabilities in support of military operations. While this technique adds a fourth dimension to the traditional 3-D data cube, it could actually lower the bandwidth requirements of existing and future imaging systems.

**SUMMARY:** To date, a comprehensive review of previous work has been performed. During the past 15 years, there has been a great deal of research on the use of polarization in military applications particularly using infrared wavelengths. With one exception, nearly all of this previous work used pan-chromatic imaging polarizers that could not discriminate the degree of polarization with wavelength. The one exception we found involved an acousto-optical tuned filter (AOTF) imager. Unfortunately, this imager was one of the first AOTF's to be built and was extremely slow at acquiring data. Consequently, the results of their work were inconclusive. Based on these findings, it was decided to build an instrument capable of measuring wavelength-dependent polarization. This instrument should be operational in the Spring of 1997.

**THESES DIRECTED:**

Petri, D., "The Use of Polarization with Hyperspectral Imaging," Master's Thesis, Naval Postgraduate School, December 1996.

Johnson, E., "Development and Testing of an Ultraviolet Hyperspectral Imager," Master's Thesis, Naval Postgraduate School, December 1996.

**DoD KEY TECHNOLOGY AREAS:** Sensors

**KEYWORDS:** Hyperspectral imaging

## PROJECT SUMMARIES

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### CONTINUOUS ELECTRON ACCELERATOR FACILITY HIGH POWER ULTRAVIOLET FREE ELECTRON LASER RESEARCH

W.B. Colson, Professor

Department of Physics

Sponsor: Southeastern University Research Association

**OBJECTIVE:** Research studies the high-average-power ultraviolet wavelength free electron laser at the continuous electron accelerator facility (CEBAF), Newport News, VA.

**SUMMARY:** CEBAF is developing a high-power UV free electron laser for industrial processing. NPS has used numerical simulations to help guide the design and development. The design also meets many of the requirements for a high-power shipboard laser weapon. CEBAF's proposed design is powered by a super-conducting RF accelerator that would produce 100 kW of laser power at UV wavelengths and would cost about \$ 30 M.

#### PUBLICATIONS:

Colson, W.B., "Short Wavelength Free Electron Lasers in 1996," Invited Review Paper, Nuclear Instruments and Methods in Physics Research, A375, 669, 1996.

Wong, R.K., Blau, J., and Colson, W.B., "Electron Beam Effects in a UV FEL," Nuclear Instruments and Methods in Physics Research, A375, 356, 1996.

Mabe, R.M., Wong, R.K., and Colson, W.B., "Optical Wavelength Modulation in Free Electron Lasers," Nuclear Instruments and Methods in Physics Research, A375, ABS 34, 1996.

Small, D.W., Wong, R.K., and Colson, W.B., "Transverse Effects in UV FELs," Nuclear Instruments and Methods in Physics Research, A375, ABS 61, 1996.

Colson, W.B., "Short Wavelength Free Electron Lasers in 1996," Nuclear Instruments and Methods in Physics Research, 1997, (submitted).

#### CONFERENCE PRESENTATIONS:

Colson, W.B., "NPS High Energy Laser Program and FEL Modeling," IR Demo Kick-Off Meeting, CEBAF, Newport News, VA, April 1996.

Colson, W.B., "Theory of High Gain Free Electron Lasers," Invited Lecture at the Eighteenth International Free Electron Laser Conference, Rome, Italy, August 1996.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Manufacturing Science and Technology

**KEYWORDS:** Free electron laser, industrial laser processing

### NORTHROP/GRUMMAN FREE ELECTRON LASER RESEARCH

W.B. Colson, Professor

Department of Physics

Sponsor: Northrop/Grumman Advanced Technology and Development Center

**OBJECTIVE:** Northrop/Grumman is interested in developing the free electron laser technology for industrial and military applications requiring high average power.

## PROJECT SUMMARIES

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**SUMMARY:** Northrop/Grumman has developed a low power free electron laser (FEL) for scientific use in the far infrared wavelength range. They are developing the accelerator and FEL technology that applies to high average power capable of defending Navy ships against sea-skimming cruise missiles. Simulations describe the performance of an FEL capable of damaging cruise missiles at a range of about 10 km. The power requirements that must be provided by the ship are studied. NPS and Northrop/Grumman have collaborated on the requirements for shipboard deployment of a 1 MW FEL.

### PUBLICATIONS:

Colson, W.B., "Theory of High Gain Free Electron Lasers," Invited Review Paper accepted by Nuclear Instruments and Methods in Physics Research.

Todd, A.M.M., Colson, W.B., and Neil, G.R., "Megawatt-Class Free Electron Laser Concept for Shipboard Self-Defense," SPIE, (submitted).

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Directed Energy Weapons

**KEYWORDS:** Free electron laser, high energy laser

### HIGH POWER INFRARED FREE ELECTRON LASERS FOR SHIP DEFENSE

W.B. Colson, Professor

Department of Physics

Sponsor: Space and Naval Warfare Systems Command

**OBJECTIVE:** SPAWAR is developing the technology for using free electron lasers (FELs) to defend ships against sea-skimming missiles.

**SUMMARY:** NPS is working with CEBAF and SPAWAR to develop the superconducting accelerator technology to power a 1 MW free electron laser for ship defense. The design must meet the requirements for a high-power shipboard laser weapon.

### PUBLICATIONS:

Blau, J., Wong, R.K., and Colson, W.B., "Optimal Power Evolution in the Boeing 1 kW FEL Oscillator," Nuclear Instruments and Methods in Physics Research A375, 358, 1996.

Small, D.W., Restivo, R.A., Wong, R.K., and Colson, W.B., "Free Electron Lasers with Short Rayleigh Length," Nuclear Instruments and Methods in Physics Research (submitted).

Ramos, L., Blau, J., and Colson, W.B., "Simulating the Trapped-Particle Instability in the Boeing 1 kW FEL Oscillator," Nuclear Instruments and Methods in Physics Research A375, ABS 54, 1996.

Anderson, E., and Colson, W.B., "Ship Design Optimization for a CEBAF Free Electron Laser," Nuclear Instruments and Methods in Physics Research (submitted).

### CONFERENCE PRESENTATIONS:

Colson, W.B., "Naval Postgraduate School Free Electron Laser Weapons," Navy MW-Class Ship Self-Defense FEL Concepts Workshop, Jefferson National Laboratory, Newport News VA, September 1996.

Small, D.W., Restivo, R.A., Wong, R.K., and Colson, W.B., "Free Electron Lasers with Short Rayleigh Length," poster paper at the Eighteenth International Free Electron Laser Conference, Rome, Italy, August 1996.



## PROJECT SUMMARIES

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Anderson, E., and Colson, W.B., "Ship Design Optimization for a CEBAF Free Electron Laser," poster paper at the Eighteenth International Free Electron Laser Conference, Rome, Italy, August 1996.

### THESIS DIRECTED:

Anderson, E.J., "Total Ship Integration of a Free Electron Laser," Master's Thesis, Naval Postgraduate School, September 1996.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Directed Energy Weapons

**KEYWORDS:** Free electron laser, high energy laser

### REMOTE SENSING-POLARIZATION EFFECTS IN THE INFRARED

Alfred W. Cooper, Professor

Department of Physics

Sponsor: Naval Command Control and Ocean Surveillance Center

**OBJECTIVE:** Develop instrumentation and techniques for measurement of environmental factors needed for prediction, analysis and modeling of infrared sensor performance in the marine boundary layer. This includes target and background signatures, emphasizing field measurement of polarization imagery.

**SUMMARY:** The split-field polarimeter attachment previously developed was tested and refined and modified to allow rapid replacement of the 8-12 band grid with one coated for the 3-5 micron band. A 12 bit data acquisition and processing system has been installed with updated computers, to allow complete four-field storage and digitization of successive frames of data, which can be down-loaded by ethernet. A pan-tilt mount was developed for the split-field polarimeter for use at Point Loma in the EOPACE Intensive Operating Period. As an additional comparative technique, polarizing filters were mounted internally in the filter wheel of the AGA-780, and used with either the 3.5 o long focal length lens or the standard 7o lens. Measurements were made over San Diego Bay using the two techniques to image sky, sea and land background scenes and naval ship targets of opportunity with both open sea and littoral background. A large set of measurements was made with the R/V POINT SUR stationary at a range of angular aspects at each of a range of distances from .5 to 5 nmi, along bearing lines from 100o to 200o. The 140o bearing was along the 20 km refraction and transmissometer path to Imperial Beach. Times ranged from early morning to late afternoon; no night-time operating periods were scheduled due to schedules for supporting measurements. Both split-field and internal filter measurements with vertical and horizontal polarization and unpolarized were made with the Point Sur as target.

### PUBLICATION:

Cooper, A.W., Lentz, W.J., and Walker, P.L., "Infrared Polarization Ship Images and Contrast in the MAPTIP Experiment," SPIE Proceedings Vol 2828, 1996.

### CONFERENCE PRESENTATION:

Cooper, A.W., Lentz, W.J., and Walker, P.L., "Infrared Polarization Ship Images and Contrast in the MAPTIP Experiment," SPIE Conference on Image Propagation through the Atmosphere," Denver CO, August 1996.

### THESIS DIRECTED:

Heisey, P.H., "Split-Field and Internally Filtered Imaging Polarimeter Development and Testing," Master's Thesis, Naval Postgraduate School, June 1996.

**DoD KEY TECHNOLOGY AREAS:** Battlespace Environments, Sensors

## PROJECT SUMMARIES

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**KEYWORDS:** Atmospheric optics, infrared sensors, IRST

### SHIP SIGNATURES AND TARGET DETECTION

Alfred W. Cooper, Professor

Department of Physics

Sponsor: Naval Command Control and Ocean Surveillance Center

**OBJECTIVE:** Improve the prediction of detection range for infrared signatures through evaluation of environmentally modified ship signatures and experimental evaluation of criteria for detection and recognition.

**SUMMARY:** Ship average temperature data developed during the PREOS92 experiment and the observed FLIR detection and recognition ranges were used to predict apparent target/background temperature difference at maximum range. Atmospheric propagation was calculated using the SEARAD code (from Dr. Zeise, NRaD). Results were compared with modeled MRTD and MDTD for a "typical" Marine Patrol FLIR. Ship skin temperatures measured on the R/V POINT SUR during the April '96 EOPACE series were reported at the EOPACE Planning Workshop in August 1996 and incorporated in the EOPACE Data Base.

#### PUBLICATION:

Groen, M.S., Koc, C., Cooper, A.W., and Pieper, R.J., "A Second Generation Visibility Based Model for Objective/Subjective MRTD," Proceedings of 1996 IRIS Specialty Group Meeting on Passive Sensors; ERIM 1996.

#### CONFERENCE PRESENTATION:

Groen, M.S., Koc, C., Cooper, A.W., and Pieper, R.J., "A Second Generation Visibility Based Model for Objective/Subjective MRTD," 1996 IRIS Specialty Group Meeting on Passive Sensors, Monterey, CA, March 1996.

#### THESIS DIRECTED:

Fu-Chau Liu, "Evaluation of Effective MDTD/MRTD for FLIR from PREOS92 Measurement Data," Master's Thesis, Naval Postgraduate School, June 1996.

**DoD KEY TECHNOLOGY AREAS:** Battlespace Environments, Sensors

**KEYWORDS:** Atmospheric optics, infrared sensors, IRST

### AEGIS PROGRAM SUPPORT IN INFRARED SEARCH, TRACK AND DETECTION

Alfred W. Cooper, Professor

Department of Physics

Sponsor: Naval Sea Systems Command

**OBJECTIVE:** The objectives of this project are to explore Advanced Technology Infrared Search and Track capabilities and define the requirements for integration with the AEGIS Anti Air Warfare defensive capabilities. The performance features of threats appropriate to IRSTD are to be compared with the AEGIS Combat System evaluate potential infrared contribution to AEGIS performance against these threats. Atmospheric performance predictions factors are to included in the evaluation.

**SUMMARY:** This project, begun in FY96, has been initiated with installation and evaluation of the IRTOOL Infra Red Simulation and Analysis model as a major tool to support the development of a performance-prediction tactical decision aid for shipboard IRST. Available sensor models have been extracted for comparison with baseline next-generation IRST parameters. A first-cut "strawman" listing of system parameters for a state of the art IRST has been

## PROJECT SUMMARIES

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assembled, and a listing of modeled generic threats to surface ships has been prepared for comparison with IRST development program requirements.

**DoD KEY TECHNOLOGY AREAS:** Battlespace Environments, Sensors, Other (Environmental Effects)

**KEYWORDS:** Atmospheric optics, infrared sensors, IRST

### NAVAL ACADEMIC CENTER FOR INFRARED TECHNOLOGY/INFRARED SURVEILLANCE AND TARGET DISCRIMINATION RESEARCH

Alfred W. Cooper, Professor

Department of Physics

Sponsor: Naval Seas Systems Command and Naval Postgraduate School

**OBJECTIVE:** To improve the imaging resolution measurement capability for polarized and unpolarized target and background infrared radiant signatures to the order of 0.1 milliradians for evaluation of polarization contrast improvement of small near horizon targets by IRST devices, and to initiate a measurement series of refractive (including mirage, looming and turbulence) effects in location of small targets on over-water paths using infrared sensors.

**SUMMARY:** During the current year an optical design was completed for a telescopic adaptor suitable for use with the modified (3-5  $\mu\text{m}$ ) Amber Focal Plane Array (FPA) camera and the dual-band (8-12  $\mu\text{m}$  and 3-5  $\mu\text{m}$ ) AGA-780 Thermovision camera. Since the required 21 inch diameter exceeded the financial restraints of the project, a modified design was constructed using a pre-existing 18 inch paraboloid ( $f/3.5$ ) mirror. The design was completed, using two custom designed germanium lenses, to a relative aperture  $f/1.81$ , which is suitable for matching to the  $f/1.87$  aperture of the AGA-780. The germanium lenses were designed and specified at NPS and constructed on contract. Performance prediction (using ZEEMAX software) and structural assembly were performed at NPS. For convenience a Newtonian configuration was adopted with the sensor mounted above the telescope. Zeemax analysis of the design adopted indicates aberration less than the diffraction limit. Final testing and application of the telescope were postponed due to the general non-availability of the Infrared sensors occasioned by equipment failures and delays in repair.

#### **PUBLICATION:**

Pieper, R.J., Cooper, A.W., and Pelegris, G., "Passive Range Estimation using Dual-Baseline Triangulation," Optical Engineering, 35(3) 685-692, March 1996.

#### **THESIS DIRECTED:**

Leite, C.D.F., "Aerothermal Effects on the Infrared Staring Seeker Performance of High Supersonic Missiles," Master's Thesis, Naval Postgraduate School, March 1996.

#### **OTHER:**

Cooper, A.W., "Naval Postgraduate School Infrared Polarized Imaging" presented to ONR Workshop on Polarization in Infrared Sensors Washington, DC, August 1996.

**DoD KEY TECHNOLOGY AREAS:** Battlespace Environments.

**KEYWORDS:** Atmospheric optics, infrared sensors, IRST.

## **PROJECT SUMMARIES**

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### **RESEARCH IN MULTIPLEXED IMAGING AND MULTISPECTRAL IMAGING**

**D.S. Davis, Associate Professor**

**Department of Physics**

**Sponsor: Naval Sea Systems Command**

**OBJECTIVE:** This is an ongoing, multi-year project whose purpose is the design and prototype development of a new type of fully multiplexed, long wavelength infrared imaging technology, capable of detecting images and multi-spectral images at wavelengths where efficient focal plane array detectors are not available.

**SUMMARY:** During FY96 the primary research tasks carried out were the second-phase design of the electromechanical servosystems that will perform the precise control functions within the prototype instrument. Key electronic circuits were designed, calculations for determining minimum acceptable drive characteristics for the servomotors were completed, motor specifications were determined, and the servomotors were procured. In addition, several software modules for the processing of multiplexed image data were written, and more detailed optical designs of portions of the optical system's layout were conducted.

#### **CONFERENCE PAPER:**

Davis, D.S., "Design for a Fully-multiplexed Imaging Fourier Transform Spectrometer," Optical Society of America Special Publications, (accepted).

**DoD KEY TECHNOLOGY AREAS:** Sensors

**KEYWORDS:** Infrared, millimeter-wave, sensors, multiplexed, multi-spectral

### **ANALYTICAL TOOL DEVELOPMENT FOR JOINT THEATER-LEVEL MODELS OF THE FUTURE**

**D.S. Davis, Associate Professor**

**Department of Physics**

**Sponsor: Naval Postgraduate School-Institute of Joint Warfare Analysis**

**OBJECTIVE:** This is an interdisciplinary research project, being conducted jointly with Professors Gaver and Jacobs of the NPS Operations Research Department. Its objective is to develop more realistic, physics-based models of sensor behavior and performance, for inclusion in future simulations of theater-level conflicts.

**SUMMARY:** Current operational models of theater-level conflicts are based upon very simple assumptions of how sensor systems (imaging devices, infrared sensors, radars, etc.) operate and provide operationally relevant information. This project has been undertaken in an effort to augment those assumptions with more physically accurate models of how such sensor systems operate, what their real capabilities are, and to what limitations they are subject. This is potentially a vast area for applied research, so we have chosen to begin by developing models that simulate basic visible-light imaging sensors mounted on satellites. The basic criteria for target detection above threshold noise will be included, as will realistic natural illumination effects, atmospheric opacity (clouds, fog), and platform over-target dwell time. If appropriate, more sophisticated optical system capabilities, such as zoom-magnification and/or wavelength selective filtering will be incorporated also.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Human-System Interfaces

**KEYWORDS:** Sensors, simulations, information warfare

## PROJECT SUMMARIES

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### COMBAT SYSTEM ELECTROMAGNETIC ENGINEERING

Robert C. Harney, Associate Professor

Department of Physics

Sponsor: Naval Sea Systems Command

**OBJECTIVE:** The objective of this project is to integrate the electromagnetic engineering (EMENG) suite of tools and top-side design principles being developed by the Combat Systems Design and Engineering Group (03K) of NAVSEA into NPS' Total Ship Systems Engineering program. The intent is to educate the TSSE students concerning the need and techniques for improving the electromagnetic characteristics and performance of a surface combatant, and to serve as a beta test site for proving out the evolving EMENG suite of computer-aided design tools. This is anticipated to be a continuing project, although continuation has not yet been approved.

**SUMMARY:** During 1996 the EMENG suite of computer-aided design and analysis tools was finally successfully loaded onto TSSE's Intergraph computer systems. Proper operation of the software was verified remotely via modem from NAVSEA. The original principal investigator (F. Fassnacht) retired at the end of September 1996, shortly after the software installation was verified. R. Harney assumed the role of principal investigator at that time. The delay in getting valid copies of the software coupled with the change of principal investigator has precluded other goals from being accomplished to date. An extension of funding into 1997 has been requested to permit continued progress toward task completion.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Surface/Under Surface Vehicles - Ships and Watercraft

**KEYWORDS:** Topside design, electromagnetic interference, computer-aided design, total ship systems engineering, combat system engineering

### DEVELOPMENT OF LASER AND LIDAR TECHNOLOGIES

Robert C. Harney, Associate Professor

Department of Physics

Sponsor: Naval Postgraduate School

**OBJECTIVE:** The objective of this project is to establish a laboratory suitable for the development of novel laser sources for lidar (laser radar) systems and studying the applications of laser and lidar technologies to military problems. Specific objectives include demonstration of a simple cw Doppler lidar for remote sensing of vibrations suitable for measurements in support of concept development and subsequent proposals, assembly of a backscatter lidar that can be used for aerosol profiling, and development of novel laser sources for upgrading these lidars as well as incorporation into new lidar applications. This is a continuing project.

**SUMMARY:** During 1996 a laser/lidar laboratory was established. Necessary door interlocks, curtains, and beamstops were installed and a laser safety operating procedure was approved. Several optical tabletops and a quantity of general purpose optical mounts and optical bench components were procured to facilitate laser and lidar breadboard activities. In addition, a personal computer was obtained along with a several electro-optical and mechanical analysis software tools necessary for experimental design and interpretation of experimental results.

The general design of the cw Doppler lidar was completed and all essential components (laser, detector, acousto-optic modulator, optics, and rf electronics) were procured. Assembly of both the lidar optical subsystem and the processing electronics was begun and was 50% complete by the end of 1996. In addition, a vibration calibration target consisting of a retroreflector mounted on a piezoelectric actuator and driven by an audio frequency signal was fabricated and its predicted amplitude vs. voltage and frequency response was verified.

A high-efficiency, short-pulse, high-prf green laser that is nearly ideal for short-range aerosol profiling was identified and a sample procured. Design of a scanning optical system and photon-counting processing electronics was begun. Procurement of additional components is expected to begin in February 1997. Conceptual design of wavelength-tunable and ultraviolet laser sources as upgrades to this aerosol-profiling lidar was also begun.

## PROJECT SUMMARIES

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**DoD KEY TECHNOLOGY AREAS:** Sensors, Chemical and Biological Defense

**KEYWORDS:** Laser, laser radar, lidar

### CAVES FLANK ARRAY AND SELF NOISE

Robert M. Keolian, Associate Professor

Department of Physics

Daphne Kapolka, LCDR, USN

Undersea Warfare Academic Group

Sponsor: Naval Sea Systems Command

**OBJECTIVE:** To develop a correlated noise cancellation technique for the CAVES fiber optic flank array. The output of noise sensors placed near internal noise sources of a submarine are correlated with the output of hull sensors to obtain running average transfer functions between the noise sources and the hull. These accumulated transfer functions and the instantaneous noise signals would then be used to subtract the self noise appearing in the CAVES sensors.

**SUMMARY:** Measurements of the complex transfer functions between various noise source positions and hull positions were made on two operational submarines (USS Hartford, USS Dolphin) and on an Intermediate Scale Model Submarine (ISMS). The stability of the transfer functions with time and operating conditions were also measured. The fraction of vibration energy at the hull that was correlated with identifiable noise sources was estimated. Measurements on simple mechanical systems, such as bars and plates, were also made to gain experience with adaptive signal processing techniques of noise cancellation.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation

**KEYWORDS:** Active noise control, active noise cancellation, sonar, sensor, self noise

### SHIP SELF NOISE CANCELLATION FOR HULL ARRAYS

Robert M. Keolian, Associate Professor

Department of Physics

Daphne Kapolka, LCDR, USN

Undersea Warfare Academic Group

Sponsor: Naval Undersea Warfare Center-Newport Division

**OBJECTIVE:** Our goal is to predict the vibration waveform at a ship hull location from measurements of the vibrations at internal sources of noise so that self noise may be subtracted from hull mounted sonars.

**SUMMARY:** Data from an Intermediate Scale Model Submarine (ISMS) that has few noise sources was obtained and analyzed. Improved non-parametric methods of system identification were used to predict signals at the hull from signals measured at the mock machinery. Once the methodology was understood for this simpler system, it was extended to the vibration measurements we made at multiple locations on the USS Hartford (SSN 768) while in transit at various depths and speeds. To help clarify how factors such as dispersion, damping, transmission time, multi-path transmission, mode conversion, and noise influence the performance of various noise cancellation techniques, simple vibrating systems of bars and plates were also investigated. Various adaptive and non-adaptive filters were used to predict the output from the input driving signals.

### THESIS DIRECTED:

Dargel, M.R., "The Influence of Physical System Parameters on the Performance of Adaptive Filters for System Identification of Mechanical Systems," Master's Thesis, Naval Postgraduate School, September 1996.

## PROJECT SUMMARIES

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**DoD KEY TECHNOLOGY AREAS:** Sensors, Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation

**KEYWORDS:** Noise cancellation, transfer function, sonar, self noise, system identification, new attack submarine

### FUNDAMENTAL ASPECTS OF NONLINEAR WAVES

Andrés Larraza, Assistant Professor

Department of Physics

Sponsor: Naval Postgraduate School

**OBJECTIVE:** To establish basic experimental and theoretical research in nonlinear waves. Two areas of research are covered. The first, absorption of sound by noise, with possible applications to noise generation and control, especially in regard to supersonic vehicles. An understanding may lead to techniques to actively control the development of shocks. The second area is AM-FM conversion with applications to tunable lasers and high data rate fiber optic communications.

**SUMMARY:** The essential process in any system of finite-amplitude noncoherent waves is the irreversible redistribution of energy among different frequencies. This gives rise to a variety of interesting and potentially useful phenomena. One such effect is the absorption of a signal by nonlinear shockless noise. Whereas this attenuation is known to be an exponential for noise in three dimensions, in one dimension it is predicted to be a *Gaussian*. This implies a breakdown in translational invariance, so that the location and strength of a source can be remotely identified. A manuscript on observations of the Gaussian in an acoustic waveguide has recently been published. In contrast to the experimental work with broad-band noise, a signal's attenuation due to nonlinear shockless noise composed of discrete frequencies were examined numerically. It was found that the observed Gaussian attenuation in the broad-band case can be approximately achieved under a variety of conditions in the discrete case.

In regard to AM-FM conversion, it was predicted that in a nonlinear dispersive medium, when the product of the dispersion and the nonlinear coefficient is positive a signal that is amplitude modulated at the source, will become frequency modulated at periodic positions in space. These results can have applications in an all-optical AM-FM conversion and in high data rate fiber optic communications. Applying these results to typical parameters in highly doped fibers it can be shown that for a 1 W source operating at a frequency of  $5.8 \times 10^{14}$  Hz and a 50% amplitude modulation of  $10^{10}$  Hz in a 10 mm<sup>2</sup> fiber, the distance for AM-FM conversion is about 20 m in doped glasses. The corresponding FM frequency spectrum has a range of about  $3.5 \times 10^{14}$  Hz. Thus an amplitude modulated green light alternating between bright and dim at the source will alternate between red and blue at a rate of  $10^{10}$  Hz at a location of about 20 m down the fiber. This mechanism allows the possibility of tunable phased-locked coherent light from a single frequency coherent source.

### PUBLICATIONS:

Larraza, Andrés, and Coleman, W.F., "Solitons, Pulse Splitting, and AM-FM Conversion in Acoustics Ducts," Journal of the Acoustical Society of America, 100, pp. 139-147, 1996.

Larraza, A., Denardo, B., and Atchley, A., "Absorption of Sound by Noise in One Dimension," Journal of the Acoustical Society of America, 100, 3554-3560, 1996.

Larraza, A., and Denardo, B., "Acoustic Waveguides As Tools in Fundamental Nonlinear Physics," to appear in Journal of the Acoustical Society of America, 101, 1997.

Larraza, A., and Denardo, B., "Acoustic Waveguides As Tools in Fundamental Nonlinear Physics," to appear in The American Institute of Physics Physics News 1996, 1997.



## PROJECT SUMMARIES

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### CONFERENCE PRESENTATIONS:

Larraza A., and Denardo B., "Absorption of Sound by Noise in One Dimension," Journal of the Acoustical Society of America 99, No. 4, Pt. 2, 2539, 1996.

### THESES DIRECTED:

Ladner, M.C., "Optical Modulator LM 0202 P Characteristics: Application to Amplitude Modulation of Argon-Ion Laser," Master's Thesis, Naval Postgraduate School, June 1996.

Wallace, H.C., "Optical Characteristics of Lexel 85 Argon-ion Laser and Gsanger LM 0202 P Modulator: Application to AM-FM Light Conversion," Master's Thesis, Naval Postgraduate School, June 1996.

Darwood J.W., "Non-electro-optic Methods of High Frequency Laser Modulation," Master's Thesis, Naval Postgraduate School, December 1996.

Tucker, J.R., "High Frequency Characterization of the Gsanger LM0202P Electro-optic Modulator," Master's Thesis, Naval Postgraduate School, December 1996.

Jang, H.J., "Numerical Simulations of Shockless Nonlinear Acoustic Noise in One Dimension," Master's Thesis, Naval Postgraduate School, December 1996.

### OTHER:

Larraza, A., "Fundamental Aspects of Nonlinear Waves: Two Examples," lecture, Department of Physics, University of California, Santa Cruz, CA, 4 October 1996.

**DoD KEY TECHNOLOGY AREAS:** Manufacturing Science and Technology, Other (Environmental Effects)

**KEYWORDS:** Nonlinear waves, random waves, nonlinear fiber optics

### ADVANCED QUANTUM DEVICE SIMULATOR DEVELOPMENT

James H. Luscombe, Associate Professor

Department of Physics

Sponsor: Texas Instruments, Inc.

**OBJECTIVE:** The purpose of this program was to assist Texas Instruments in developing a nanoelectronic device modeling tool. In particular, the emphasis was on computing the current-voltage characteristics of resonant-tunneling diodes, a key component of nanoelectronic device technology.

**SUMMARY:** The current-voltage characteristics of a wide-variety of resonant-tunneling diode device structures using several versions of prototype code supplied by Texas Instruments was computed. The use of supercomputers was essential for this project and porting the code to various supercomputers was a major issue. Through the DoD High Performance Computing Modernization Program, supercomputers located in Maui, Hawaii and Wright-Patterson AFB were utilized. In 1996, Texas Instruments sold the division of the corporation that sponsored this project, rendering the future of the program uncertain. This project will most likely not be continued into the future.

### THESIS DIRECTED:

Porter, R.M., "Simulation of Resonant Tunneling Diodes," Master's Thesis, Naval Postgraduate School, June 1996.

**DoD KEY TECHNOLOGY AREAS:** Electronics, Modeling and Simulation



## PROJECT SUMMARIES

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**KEYWORDS:** Nanoelectronics, nanotechnology, modeling

### DEVELOPMENT OF QUANTUM DEVICE MODELS

James H. Luscombe, Associate Professor

Department of Physics

Sponsor: Naval Postgraduate School

**OBJECTIVE:** The goal of this program is to develop theoretical models of the electronic, magnetic and structural properties of materials and systems at the nanometer length scale. While the primary emphasis is on developing models of heterostructure quantum electron devices, Nano-scale magnetic structures are also of interest. This is a continuing project.

**SUMMARY:** A computer code to model Bloch oscillations in semiconductor superlattices within the effective-mass approximation was developed. This tool was used to predict a spatially selective photo-excitation process that should significantly reduce the dephasing of Bloch oscillation signals that are attributed to interface roughness in epitaxially grown superlattices. Also developed was a classical-spin model of a magnetic molecular cluster to compute correlation functions and the magnetic susceptibility. This theory was used to develop a model of the nuclear-magnetic-resonance (NMR) spin-lattice relaxation time in small magnetic clusters. A new method to compute Fermi-Dirac integrals, which are used extensively in quantum device modeling was developed as well. The method works by numerically accelerating the convergence of power-series expansions of the Fermi-Dirac integral.

### PUBLICATIONS:

Luscombe, J.H., Luban, M., and Reynolds, J.P., "Finite-Size Scaling of the Glauber Model of Critical Dynamics," Physical Review E, Vol. 53, No. 6, p. 5852-60, 1996.

Luscombe, J.H., and Luban, M., "Nonequilibrium Structure Factor for Conserved-Spin Dynamics: Abrupt Temperature Increase," Physical Review E, Vol. 54, No. 3, p.2266-90, 1996.

Luscombe, J.H., and Luban, M., "Nonequilibrium Structure Factor for the Disordering of Adsorbed Monolayers," Surface Science Letters 365, L676-L680, 1996.

Luscombe, J.H., Luban, M., and Reynolds, J.P., "Finite-Size Scaling of the Glauber Model of Critical Dynamics," Bulletin of the American Physical Society, Vol. 41, p. 611, 1996.

Luscombe, J.H., and Luban, M., "Nonequilibrium Structure Factor for Diffusive Kinetics: New Predictions for Disordering," Bulletin of the American Physical Society, Vol. 41, p. 776, 1996.

### CONFERENCE PRESENTATIONS:

Luscombe, J.H., and Luban, M., "Nonequilibrium Structure Factor for Diffusive Kinetics: New Predictions for Disordering," Meeting of the American Physical Society, St. Louis, MO, 18-22 March 1996.

Luscombe, J.H., Luban, M., and Reynolds, J.P., "Finite-Size Scaling of the Glauber Model of Critical Dynamics," Meeting of the American Physical Society, St. Louis, MO, 18-22 March 1996.

Luscombe, J.H., and Luban, M., "Nonequilibrium Structure Factor for Conserved-Spin Dynamics: Abrupt Temperature Increase," Meeting of the American Physical Society, St. Louis, MO, 18-22 March 1996.

Borsa, F Jang, Z., Shastri, A., Luban, M., Lascialfari, A., Gatteschi, D., and Luscombe, J.H., "Proton Spin-Lattice Relaxation and Spin Dynamics in Magnetic Molecular Clusters," Meeting of the American Physical Society, Kansas City, MO, 17-21 March 1997.

## PROJECT SUMMARIES

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Reynolds, J.P., Luban, M., and Luscombe, J.H., "Long-Lived Quasi-Periodic Bloch Oscillations by Spatially Selective Photoexcitation," Meeting of the American Physical Society, Kansas City, MO, 17-21 March 1997.

Luscombe, J.H., Luban, M., and Borsa, F., "Classical Heisenberg Model of a Ring Nanostructure: Correlation Functions and Susceptibility," Meeting of the American Physical Society, Kansas City, MO, 17-21 March 1997.

### THESES DIRECTED:

Thompson, J.S., "High-Speed Integration of Fermi-Dirac Integrals," Master's Thesis, Naval Postgraduate School, June 1996.

Coppeans, W., "Simulation of Bloch Oscillations," Master's Thesis, Naval Postgraduate School, December, 1996.

**DoD KEY TECHNOLOGY AREAS:** Electronics, Materials, Processes and Structures, Modeling and Simulation

**KEYWORDS:** Nanoelectronics, nanotechnology, nanomagnetism

### NAVAL POSTGRADUATE SCHOOL LINEAR ACCELERATOR AND FLASH X-RAY MACHINE

**X.K. Maruyama, Professor**

**Department of Physics**

**Sponsor: Naval Postgraduate School**

**OBJECTIVE:** The radiation sources at NPS, the 100 MeV RF electron linear accelerator and the 1.7 MV pulsed flash x-ray machine are required for a number of projects at NPS, including the study of unipolar arcing plasma physics, investigation of novel sources of coherent radiation and radiation effects in materials and electronic devices. These radiation sources are maintained by the Physics Department, but are available to a variety of investigators from the Naval Postgraduate School and their associated external collaborators. These radiation source facilities are also used for classroom course instruction. In addition to the use of radiation sources, the facility capabilities are maintained to provide NPS with resources for pulsed power technology.

**SUMMARY:** In CY96, Duane Salisbury, an ECE student was able to conduct a thesis experiment irradiating a new solid state device to investigate its application for the space environment. Michael Chase, a Combat Systems student was able to investigate the development of Khumakov lenses for x-ray focussing. Joseph Thien and James Barrows were able to complete a thesis investigating parametric x-radiation. Fred Beach used the facility resources to design and construct an electromagnetic railgun.

### PUBLICATIONS:

Abe, K., Akagi, T., Anthony, P.L., Antonov, R., Arnold, R.G., Averett, T., Band, H.R., Bauer, J.M., Borel, H., Bosted, P.E., Breton, V., Button-Shafer, J., Chen, J.P., Chupp, T.E., Cledenin, J., Comptour, C., Coulter, K.P., Court, G., Crabb, D., Daoudi, M., Day, D., Dietrich, F.S., Dunne, J., Dutz, H., Erbacher, R., Fellbaum, J., Feltham, A., Fonvieille, H., Friez, E., Garvey, D., Gearhart, R., Gomez, J., Grenier, P., Griffioen, K.A., Hoibraten, S., Hughes, E.W., Hyde-Wright, C., Johnson, J.R., Kwall, D., Klein, A., Kuhn, S.E., Kuriki, M., Lindgren, R., Liu, T.J., Lombard-Nelsen, R.M., Marroncle, J., Maruyama, T., Maruyama, X.K., McCarthy, J., Meyer, W., Meziani, Z.E., Minehart, R., Mitchell, J., Morgenstern, J., Petratos, G.C., Pitthan, R., Pocanic, D., Prescott, C., Prepost, R., Raines, P., Raue, B., Reyna, D., Rijllart, A., Roblin, Y., Rochester, L., Rock, S.E., Rondon, O.A., Sick, I., Smith, L.C., Smith, T.B., Spengos, M., Staley, F., Steiner, P., St. Laurant, S., Stuart, L.M., Suekane, F., Szalata, Z.M., Tang, H., Terrien, Y., Usher, T., Walz, D., White, J.L.K., Witte, K., Young, C., Youngman, B., Yuta, H., Zapalac, G., Zihlmann, B., Zimmerman, D., (The E143 Collaboration), "Measurement of the Proton and Deuteron Spin Structure Function  $g_2$  and Asymmetry  $A_2$ ," *Physical Review Letters* 76, 587 (1996). Abe, K., Garvey, D., Maruyama, X.K., et al (The E143 Collaboration), "Measurement of the Proton and Deuteron Spin Structure Function  $g_1$  in the Resonance Region," SLAC-PUB-7242, September 1996.

## PROJECT SUMMARIES

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### CONFERENCE PRESENTATION:

Maruyama, X.K., "Transition Radiation Based Tools for Characterizing Charged Particle," Fourteenth International Conference on the Application of Accelerators in Research & Industry, University of North Texas, Denton, TX, 6-9 November 1996.

### THESES DIRECTED:

Barrows, J.E., "Parametric X-Radiation from Mosaic Graphite: New Results and Reconciliation of Previous Experiments," Master's Thesis, Naval Postgraduate School, March 1996.

Beach, F.C., "Design and Construction of a One Meter Electromagnetic Railgun," Master's Thesis, Naval Postgraduate School, June 1996.

**DoD KEY TECHNOLOGY AREAS:** Other

**KEYWORDS:** Accelerator, klystron, linac, flash x-ray, radiation, parametric x-ray, railgun, radiation effects

### LIQUID METAL ION GUN FLIGHT EXPERIMENT

R.C. Olsen, Associate Professor

Department of Physics

Sponsor: National Aeronautics and Space Administration

**OBJECTIVE:** Prepare charge control experiment for launch on the European Space Agency (ESA) Cluster satellite mission. NPS responsibilities are to procure tile substrate, support charging analysis.

**SUMMARY:** The project has a small setback when the Ariane V launch vehicle blew up in February 1996. There is a modest effort to recover some science ongoing. Fresh tile materials were provided for the construction of a new instrument.

**DoD KEY TECHNOLOGY AREAS:** Space Vehicles

**KEYWORDS:** Spacecraft charging, ion beams, spacecraft- environment interactions

### APPLICATION OF HYPERSPECTRAL IMAGING TO NAVAL APPLICATIONS

R.C. Olsen, Associate Professor

Department of Physics

Sponsor: Naval Research Laboratory

**OBJECTIVE:** Address the application of multispectral and hyperspectral imaging to Naval needs; participate in activities utilizing HYDICE and other instruments; and analyze data collected during these experiments.

**SUMMARY:** Hyperspectral image data have been acquired from experimental sensors, and are being analyzed using non-literal techniques. The objectives are to identify target signatures, and other features of interest in land and littoral scenes. Data from HYMISMO projects have been analyzed. Students participated in data collections with HYDICE and other systems.

### THESIS DIRECTED:

Bergman, S.M., "The Utility of Hyperspectral Data to Detect and Discriminate Actual and Decoy Target Vehicles," Master's Thesis, Naval Postgraduate School, December 1996

## **PROJECT SUMMARIES**

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**DoD KEY TECHNOLOGY AREAS:** Sensors

**KEYWORDS:** Remote sensing, targeting, trafficability

### **APPLICATION OF NATIONAL SYSTEMS TO LITTORAL WARFARE**

**R.C. Olsen, Associate Professor**  
**Department of Physics**  
**Sponsor: Chief of Naval Operations**

**OBJECTIVE:** Address the application of data acquired with national systems to littoral warfare and study the mine detection problem in littoral environments.

**SUMMARY:** Data from national systems previously acquired were analyzed. New data from the SEBASS instrument were analyzed to study the utility of spectral imagery in the thermal IR wavelength range.

#### **THESIS DIRECTED:**

Collins, B.H., "Thermal Imagery Spectral Analysis," Master's Thesis, Naval Postgraduate School, September 1996.

**DoD KEY TECHNOLOGY AREAS:** Sensors

**KEYWORDS:** Remote sensing, national systems, mine warfare, TENCAP

### **NEAR-SHORE BATHYMETRIC ESTIMATES FROM HYPERSPECTRAL VISIBLE IMAGERY**

**R.C. Olsen, Associate Professor**  
**Department of Physics**  
**Sponsor: Chief of Naval Operations**

**OBJECTIVE:** Address the application of hyperspectral imagery to obtaining bathymetry and apply this knowledge to the mine detection problem.

**SUMMARY:** Data from the HYDICE sensor collected over Lake Tahoe were analyzed. The Bierwirth algorithm was applied, utilizing spectral segmentation techniques to remove the influence of varying bottom spectra.

#### **THESIS DIRECTED:**

Stuffle, L.D., "Bathymetry from Hyperspectral Imagery," Master's Thesis, Naval Postgraduate School, December 1996.

**DoD KEY TECHNOLOGY AREAS:** Sensors

**KEYWORDS:** Remote sensing, national systems, mine warfare, TENCAP

### **THEATRE AIR DEFENSE PROGRAMS, THESES, AND CURRICULUM SUPPORT**

**Gordon Schacher, Professor**  
**Department of Physics**  
**Sponsor: Program Executive Office-Theater Air Defense**

**OBJECTIVE:** The purpose of this project is to bring the Combat Systems curriculum and research into closer alignment with the needs of the sponsor.

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**SUMMARY:** The following activities were supported: Student Travel, Theses, Course Development, Faculty Development, TAD Projects. Thesis support was for: Ultraviolet IFF system and infrared multiplexed imaging system. Faculty and Course Development were in the following areas: Opto-Electronics, Electro-Optic Devices, and Mine Detection. Applied projects that provided support directly to TAD programs were begun in: CEC Modeling, Ship Self Defense, and Command Center of the Future

**DoD KEY TECHNOLOGY AREAS:** Command, Control and Communications, Sensors, Modeling and Simulation, Conventional Weapons, Battlespace Environments

**KEYWORDS:** Combat systems, modeling and simulation education and training

### DEVELOP ASSESSMENT PROCESS FOR CHEMICAL/BIOLOGICAL HAZARD MODELS

Gordon Schacher, Professor

Department of Physics

Sponsor: Office of the Assistant Secretary of Defense

**OBJECTIVE:** The purpose of this work was to develop a process by which chem/bio hazard assessment models/simulations could be evaluated

**SUMMARY:** In the early stages of the work it was decided that the only viable way to evaluate an assessment model is to determine how well it meets the requirements of a specific user. Thus, the process developed consists of three parts: User Requirements Form, Model Attributes Form, and Model Evaluation Form. Each of these forms is extensive, attempting to capture all user needs that would impact model configuration, and all model attributes that determine its physical validity and whether it is applicable to the user's resources. A team tested the evaluation process on two existing DoD models, and these results were used to recommend a hazard assessment configuration for U.S. Forces, Korea.

#### PUBLICATION:

Schacher, G., "Evaluation Process for Chemical/Biological/Radiological Hazard Assessment Models," NPS-PH-96-006, 1996.

**DoD KEY TECHNOLOGY AREAS:** Chemical and Biological Defense, Modeling and Simulation

**KEYWORDS:** Chemical and biological defense, modeling and simulation, atmospheric transport and diffusion

### BOTTOM REVERBERATION DATA ANALYSIS AND PROPAGATION MODELING OF COMPLEX MULTIPATHS (FY96)

Kevin B. Smith, Assistant Professor

Department of Physics

Sponsor: Office of Naval Research

**OBJECTIVE:** The scientific objective of this work is to understand the limits of signal resolution imposed by complex forward-propagating multipaths. This will be studied in both deep and shallow water environments with data from the 1993 ARSRP acoustics cruise used to compare deep water results. Proposed here is a two-year program involving data analysis, model predictions, and the software development to support and improve both.

**SUMMARY:** High quality acoustic reverberation data was collected during the Acoustic Reverberation Special Research Program's (ARSRP) main acoustics cruise in the summer of 1993. The ability to correlate these measured returns with bathymetric features depends on the signal resolution. A study of the effects of multipath propagation on signal resolution is proposed. Analysis of the measured data will provide a means of confirming predictions of these

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effects. An advanced PE propagation model will be used to quantify these effects in the ARSRP environment. Incorporating shallow water databases will provide a means of studying similar effects in a littoral environment. This research is a continuation of the FY95 research sponsored jointly by ONR and the Scripps Institution of Oceanography.

### PUBLICATIONS:

Smith, K.B., Hodgkiss, W.S., and Tappert, F.D., "Propagation and Analysis Issues in the Prediction of Long-Range Reverberation," Journal of the Acoustical Society of America, 99, 1387-1404, 1996.

Smith, K.B., and Cushman, E.B., "A Comparison of Quasi-CW and Broadband Travel Time Techniques in the Prediction of Long-range Reverberation," Journal of the Acoustical Society of America, (submitted).

### CONFERENCE PRESENTATION:

Smith, K.B., "Bottom Interactions of Pulse Propagation and Corresponding Real-Time Reverberation," Journal of the Acoustical Society of America Supplement, Vol. 99, pp. 2552, 1996, (Invited paper.)

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Other (Environmental Effects, Acoustic Reverberation, Sonar Performance)

**KEYWORDS:** Acoustic reverberation, propagation, multipaths

### AN EXAMINATION OF 3D, BROADBAND ACOUSTIC PROPAGATION PHYSICS IN A LITTORAL OCEAN ENVIRONMENT - AN EXTENSION TO AN ONR PRIMER FIELD STUDY IN THE MID-ATLANTIC BIGHT

Kevin B. Smith, Assistant Professor

Department of Physics

Sponsor: Office of Naval Research

**OBJECTIVE:** The scientific objective of this work is to study the physics and predictability of 3-D, broadband acoustic propagation upslope onto the continental shelf in the presence of strong oceanographic frontal features, specifically in the vicinity of the mid-Atlantic Bight.

**SUMMARY:** With the emphasis of USW shifting to littoral environments, the understanding and, ultimately, prediction of acoustic propagation in the vicinity of the shelf break becomes increasingly important. The sloping bathymetry, the extreme seasonal changes in the vertical sound-speed structure and the significant horizontal variability generated by the shelf-break front are just a few of the environmental factors that make this problem both interesting and complex. Under the PRIMER initiative, the Office of Naval Research is sponsoring a multi-year study of acoustic propagation in the region of the North Atlantic Bight off the coast of New Jersey. This region is of interest due to the combination of sloping bathymetry near the continental shelf and the strong oceanographic frontal features associated with the Gulf Stream.

The general purpose of this project is to study the effects of the frontal region on acoustic propagation onto the shelf. This research is a complementary study of propagation effects and data analysis. Specifically, the influence of three-dimensional propagation effects and their influence on the prediction of broadband measurements in similar oceanographic regions shall be addressed. In addition to the experimental components already in place, the deployment of explosive SUS charges throughout the area at the beginning and end of the study was coordinated. The addition of these very broadband sources will provide valuable information on specific frequency dependent phenomena. In preparation for the shallow water acoustic modeling that will be required to achieve these goals, upgrading of the acoustic propagation model which was developed with Professor Fred Tappert of the University of Miami, has been accomplished. Some of the recent work has been published as an invited book chapter.

## PROJECT SUMMARIES

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### PUBLICATIONS:

Smith, K.B., "Modeling the Effects of Azimuthal Coupling on Acoustic Propagation in the Presence of 3-dimensional, Rough Ocean Interfaces Using the Parabolic Approximation," Special Issue of Theoretical and Computational Acoustics, D. Lee, Y-H Pao, M.H. Shultz, and Y.-C. Teng (eds), World Scientific Publishing Co., 115-131, 1996, (Invited paper).

Tappert, F.D., Smith, K.B., and Wolfson, M.A., "Parabolic Equation Models: Split-step Fourier Methods," Special Issue of Mathematical Modeling and Scientific Computing, Computer Modeling in Ocean Acoustics, 1996, (Invited chapter, in press).

Smith, K.B., "Three-dimensional Effects on Broadband Pulse Propagation Near Shelf Breaks," Proceedings of International Conference on Shallow Water Acoustics, Beijing, China, 21-25 April 1997, (submitted).

Smith, K.B., "Influences of Sediment Interface and Volume Variability on Pulse Resolution," Proceedings of High Frequency Acoustics in Shallow Water Conference, SACLANT, La Spezia, Italy, 30 June-4 July 1997, (submitted).

### CONFERENCE PRESENTATION:

Smith, K.B., and Chiu, C.-S., "Three-dimensional Effects on Broadband Pulse Propagation Near the Mid-Atlantic Bight," Journal of the Acoustical Society of America, Supplement, Vol. 100, pp. 2737, 1996.

### THESES DIRECTED:

Yuan, Mei-Chun, "Effects of Shallow Water Bottom Interface Roughness and Volume Fluctuations on Broadband Pulse Resolution," Master's Thesis, Naval Postgraduate School, June 1996.

D'Agostino, A.F. "Three Dimensional Acoustic Effects in the Middle Atlantic Bight," Master's Thesis, Naval Postgraduate School, June 1996.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Other (3-D Acoustic Propagation, Littoral Environments)

**KEYWORDS:** Acoustic propagation, azimuthal coupling, littoral environments

### EXAMINATION OF PHYSICS MISMATCH INFLUENCE ON LOCALIZATION

Kevin B. Smith, Assistant Professor

Department of Physics

Sponsor: Naval Undersea Warfare Center

**OBJECTIVE:** The scientific objective of this work is to study the influence of the physics mismatch due to less-than-ideal acoustic ray model predictions on the localization of full-wave signals and to coordinate future research efforts towards a system demonstration of passive transient localization.

**SUMMARY:** A study of issues relating to the localization of passive transients is being coordinated by the Naval Undersea Warfare Center - New London. This research focuses on an examination of the influence of physics mismatch in the prediction of the acoustic propagation. A signal autocorrelation matching algorithm is used to produce the ambiguity surface for the localization. A full-wave, parabolic equation model is employed to produce a synthetic signal and a reciprocal prediction to provide a baseline for the mismatch. Predictions from a ray model based on the same parabolic approximation are then matched to the synthetic signal. By comparing this ambiguity surface with the baseline, the influence of the physics mismatch due to ray predictions can be quantified. Several aspects of the ray model (e.g., phase and amplitude information) can be independently affected providing information on model degradation of



## PROJECT SUMMARIES

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localization performance. In addition to the scientific research involved in this project, is the task of the coordination of the larger program of passive transient localization. These additional responsibilities include coordinating the direction and interaction of various researchers towards a common goal of producing a working system capable of being employed by the fleet.

### **PUBLICATION:**

Miller, J.H., Benson, J.L., Chiu, C.-S., and Smith, K.B., "FY95 Results: Transient Localization Project at NPS," Naval Postgraduate School Technical Report, NPS-UW-96-001PR, 1996.

### **THESIS DIRECTED:**

DeKooter, Peter, "Variations on Autocorrelation Matching and the SIFT Localization Algorithm," Master's Thesis, Naval Postgraduate School, March 1996.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Sensors, Other (Localization)

**KEYWORDS:** Parabolic equation model, Hamiltonian ray model, matched field, transient localization

### **EFFECTS OF OCEAN MESOSCALE FEATURES ON ADIABATIC MODE TRAVEL TIMES**

**Kevin B. Smith, Assistant Professor**

**Department of Physics**

**Sponsor: Naval Postgraduate School**

**OBJECTIVE:** The objective of this work is to develop a theory on the effects of ocean mesoscale perturbations on adiabatic mode travel times. Confirmation of the theory will be in the form of numerical predictions obtained by a broadband, range-dependent parabolic equation model from which the field can be decomposed into local normal modes. The modeled ocean environment will be composed of a superposition of Rossby waves providing realistic mesoscale ocean features.

**SUMMARY:** The use of adiabatic normal mode theory is justifiable in environments containing slowly modulating, range-dependent perturbations. In such cases, the calculation of the field response due to an active source measured at some distant range is greatly simplified since coupling between modes is considered negligible. The amplitudes of the local modes only in the vicinity of the source and receiver need to be computed while the effect of the range dependence is accounted for simply by integrating the horizontal modal wavenumber along the propagation path. Computing the excitation of the modes by the source then provides the relative amplitudes of the modes at any range regardless of how they adjust to the local environment. However, while such environments may not affect relative modal amplitudes, slowly modulating sound speed perturbations may still affect mode travel times over long distances. A theoretical model of the effect on mode travel times due to a superposition of baroclinic Rossby waves will be developed. The predictions can then be compared to results obtained from a broadband, range-dependent parabolic equation model from which the field can be decomposed into local normal modes. The effects on tomography or source localization in the presence of such an environment will also be discussed. A generalized, statistical description of the travel time effect can then be developed and compared with predictions made employing an advanced eddy-resolving ocean dynamics model. This research provides the core of Amy R. Smith's dissertation.

### **PUBLICATIONS:**

Smith, A.R., Smith, K.B., and Chiu, C.-S., "Effect of Ocean Mesoscale Features on Adiabatic Mode Travel Times," Proceedings of the 3rd European Conference on Underwater Acoustics, pp. 297-302, 24-28 June 1996.



## PROJECT SUMMARIES

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### CONFERENCE PRESENTATIONS:

Smith, A.R., Smith, K.B., and Chiu, C.-S., "Effect of Ocean Mesoscale Features on Adiabatic Mode Travel Times," Presented at the 3rd European Conference on Underwater Acoustics, 24-28 June 1996.

### THESIS DIRECTED:

Smith, Amy R., "Effect of Ocean Mesoscale Features on Adiabatic Mode Travel Times," Ph.D. Dissertation, Naval Postgraduate School, March 1996.

**DoD KEY TECHNOLOGY AREAS:** Modeling and Simulation, Other (Environmental Effects)

**KEYWORDS:** Acoustic pulse propagation, adiabatic modes, ocean mesoscale features

### BASIC RESEARCH IN BURSTING BUBBLES AND OCEAN AEROSOL SOURCE FUNCTIONS

Donald E. Spiel, Senior Lecturer

Department of Physics

Sponsor: Office of Naval Research

**OBJECTIVE:** The objective of this continuing research is to determine the parameters of bursting ocean bubbles relevant to air-sea interactions and the marine boundary layer. Included are the number, size, and ejection parameters of both jet and film droplets.

**SUMMARY:** Details of the bubble's cap opening, the "burst," have been studied. It has been determined that the cap does not simply disintegrate upon bursting as previously thought; but that, rather, a hole appears somewhere on the surface, usually at the cap's edge, which then propagates in an orderly manner until the entire cap is consumed. The speed of this opening process has been measured as a function of bubble size. The cap's thickness can be calculated given this speed. A hypothesis to explain the origin of film drops has been advanced.

### PUBLICATIONS:

Spiel, D.E., and De Leeuw, G., "Formation and Production of Sea Spray Aerosol," Journal of Aerosol Science 27, pp. 65-66, 1996

**DoD KEY TECHNOLOGY AREAS:** Battlespace Environments, Electronic Warfare, Modeling and Simulation

**KEYWORDS:** Air-sea interaction, jet drops, film drops, gas exchange

### HIGH RESOLUTION STRATOSPHERIC PROPAGATION MEASUREMENTS FOR THE AIR BORNE LASER PROGRAM

D.L. Walters, Associate Professor

Department of Physics

Sponsor: U.S. Air Force-Phillips Laboratory

**OBJECTIVE:** To develop sensors capabilities and collect stratospheric turbulence data critical to the propagation issue facing the Air Borne Laser Program, which is a key part of the DoD Theater Missile Defense Initiative.

**SUMMARY:** A single temperature probe microthermal balloon system was developed and deployed at White Sands Missile Range, N.M., in conjunction with a Joint Army, Air Force and Navy field experiment that included the ARGUS KC135 instrumented aircraft and the US Army 50 MHz stratospheric radar. The NPS system achieved 500 uK rms noise at a 320 Hz sample rate that translates into 3-cm vertical temperature resolution in the stratosphere.

## PROJECT SUMMARIES

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### CONFERENCE PRESENTATION:

Walters, D.L., Galarowicz, D.G., and Bradford, W., "High Resolution Stratospheric Turbulence Measurements," Workshop on Atmospheric Propagation for ABL, Kirkland Air Force Base, NM., 15 December 1996.

**DoD KEY TECHNOLOGY AREAS:** Battlespace Environments, Directed Energy Weapons

**KEYWORDS:** Stratospheric turbulence, balloon microthermal

### OPTICAL ASSESSMENT FOR ADAPTIVE OPTICAL SYSTEMS

**D.L. Walters, Associate Professor**

**Department of Physics**

**Sponsor: U.S. Air Force-Phillips Laboratory**

**OBJECTIVE:** To collate and analyze atmospheric optical measurements made by NPS over the last decade in order to quantify, compare and relate different geographic locations. The primary goal is for ultimate placement of laser optical communication systems for space ground, ground space applications.

**SUMMARY:** Ten years of atmospheric coherence length and isoplanatic angle measurements were collated and compared, with an emphasis on enumerating the statistical characteristics of the data. Understanding the atmospheric turbulence parameters is a key part determining the viability of optical communication systems for multi Giga bit communication links.

### PUBLICATION:

Walters D.L., and Bradford, L.W., "Measurements of  $R_0$  and  $\Theta$  Two Decades and 18 Sites," (accepted for publication).

**DoD KEY TECHNOLOGY AREAS:** Battlespace Environments, Electronics

**KEYWORDS:** Optical Communication Systems, atmospheric coherence length, isoplanotic angle measurements

### MINE WARFARE MEASURES FOR OPERATIONAL SYSTEMS

**D.L. Walters, Associate Professor**

**Department of Physics**

**Sponsor: Program Executive Office-Mine Warfare**

**OBJECTIVE:** To investigate high resolution, imaging, synthetic aperture sonars for mine detection, identification and classification.

**SUMMARY:** A FM chirped compressed pulse, synthetic aperture sonar was developed and used for mine identification and detection. Target speckle turned out to be the key limitation to achieving high image resolution of the working, 25-50 kHz system.

### THESIS DIRECTED:

Lim Ghin Huat, "Experimental Investigation of a High Resolution Sonar," Masters Thesis, Naval Postgraduate School, March 1996.

## PROJECT SUMMARIES

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**DoD KEY TECHNOLOGY AREAS:** Surface/Under Surface Vehicles - Ships and Watercraft, Battlespace Environments

**KEYWORDS:** Synthetic aperture sonar, sonar, FM chirp, speckle

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## 1996 THESIS ABSTRACTS

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### **TROPOSPHERIC EFFECTS ON UHF RADIO WAVE PROPAGATION AT LOW ELEVATION ANGLES**

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**B.S., United States Naval Academy, 1989**

**Master of Science in Applied Physics-September 1996**

**Advisor: David D. Cleary, Department of Physics**

**Second Reader: Gus K. Lott, Department of Electrical and Computer Engineering**

The effects of low elevation angles on radio wave propagation are determined, specifically in application to geolocation. Currently, data received at low elevation angles, generally those angles less than about  $10^\circ$ , are of little use due to the impact of the troposphere, obstacle shielding, multipath, and other issues that are not completely resolved. An experiment was conducted from 23 October to 03 November 1995 to study the practicality of using low elevation angle data for precise geolocation. The objectives were to first define tropospheric and other low elevation angle effects on ultra high frequency (UHF) geolocation by means of an experiment and analysis. The second objective was to develop compensation techniques. This analysis establishes a minimum value of  $1.6^\circ$  for a usable elevation angle. This analysis also shows the error from tropospheric effects, quantified in the miss distance, experienced at low elevation angles. Comparisons with geolocation cases clarifies the extent of the remaining problem at low elevation angles. Use of the Hopfield tropospheric model is shown to be effective in most instances.

### **TOTAL SHIP INTEGRATION OF A FREE ELECTRON LASER (FEL)**

**Eric J. Anderson-Lieutenant, United States Navy**

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**Master of Science in Mechanical Engineering-September 1996**

**Advisors: Charles N. Calvano, Department of Mechanical Engineering**

**William B. Colson, Department of Physics**

High-power Free Electron Lasers (FELs), capable of stopping an incoming anti-ship missile, can be an effective addition to the self-defense system of a modern naval combatant. A shipboard FEL must be compact, efficient, and capable of reliable operation in a naval environment. This thesis explores the feasibility of integrating a 1 MW infrared FEL aboard a surface combatant from a Total Ship Systems perspective. A study of system aspects including prime power systems and vibrational effects will be addressed to determine the overall ship impact.

A 1 MW FEL requires about 10 MW of electrical power from the shipboard prime power system if run continuously or approximately 2 MW using energy storage. A DDG-51 Arleigh Burke class Destroyer has sufficient reserve generating capacity to produce the required electrical power for the FEL. The required prime power electrical distribution system is compatible with the ship's main propulsion gas turbines and will weigh 42900 kg and occupy  $35 \text{ m}^3$ . Shipboard vibrations which will have the greatest influence on the FEL are generally characterized at frequencies below 50 Hz and have amplitudes approaching  $900 \mu\text{m}$ . The effect of these vibrations can reduce to an acceptable level which will permit continuous operation in the maritime environment. From a Total Ship Systems perspective the FEL can be accommodated in a DDG-51 class destroyer with negligible impact.

### **AN INVESTIGATION OF SURFACE WAVES USING A TWO-AXIS SOURCE-RECEIVER COMBINATION**

**Anthony J. Anglin-Lieutenant, United States Navy**

**B.S., United States Naval Academy, 1990**

**Master of Science in Engineering Acoustics-June 1996**

**Advisors: Anthony A. Atchley, Department of Physics**

**Donald L. Walters, Department of Physics**

The goals of this thesis are: 1) to design and test a two-axis surface wave source and two axis surface wave receiver, and 2) investigate surface waves to detect buried objects in water saturated sand. Results of measurements confirm the ability to generate particle motions in water saturated sand consistent with surface wave excitation. However, limita-

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tions in the size of the test tank prohibit a thorough investigation of the ability of the source and receiver to selectively excite and detect surface waves.

### **PARAMETRIC X-RADIATION FROM MOSAIC GRAPHITE: NEW RESULTS AND RECONCILIATION OF PREVIOUS EXPERIMENTS**

**James E. Barrows-Lieutenant, United States Navy**

**B.S., University of Idaho, 1988**

**Master of Science in Applied Physics-March 1996**

**Advisor: Xavier K. Maruyama, Department of Physics**

This thesis explores the effects of mosaic graphite on the yield of parametric x-radiation (PXR). PXR is the Bragg scattering of virtual photons associated with the Coulombic field of relativistically charged particles interacting with the atomic planes of a crystal. PXR was measured from three samples of mosaic graphite crystals with differing mosaicities. The number of photons per electron was calibrated with the fluorescent x-ray yield from a thin silver foil backing on each of the mosaic crystals. The detector angular field of view was narrowed from previous experiments. Improvements were made in the re-analysis of previous experiments by considering the thick target effects of the x-ray absorption. Previous experiments had erroneously assumed that the calibration fluorescent targets were thin. Re-analysis of previous data using corrections for solid angle, crystal absorption factors and effective thickness resulted in yields similar to those obtained in this work.

### **DESIGN AND CONSTRUCTION OF A ONE METER ELECTROMAGNETIC RAILGUN**

**Fred Charles Beach-Lieutenant Commander, United States Navy**

**B. S., University of Oklahoma, 1982**

**Master of Science in Physics-June 1996**

**Advisors: Richard Harkins, Department of Physics**

**William Maier II, Department of Physics**

**Xavier Maruyama, Department of Physics**

The acceleration of projectiles through the use of electromagnetic forces (Railguns) has many advantages over conventional methods. Foremost are the higher velocities which can be achieved and the reduction in firing platform sensitivity to hits. Projectile velocities on the order of 3-4 kilometers per second allow the use of "kinetic energy kill" projectiles which are effectively inert munitions. Additionally, by using purely electromotive force for the acceleration, the need for explosive propellants is eliminated.

A one meter Electromagnetic Railgun was designed and constructed to serve as a test bed for research into alternative armature materials, rail/armature plasma effects, and current pulse forming techniques. A modular approach was used to allow independent changes in power supply, pulse forming network, bore configuration, and gun augmentation.

### **DEVELOPMENT OF A SURVIVABILITY AND LETHALITY ASSESSMENT CENTER (SLAC) AT NPS**

**Gary G. Bishop-Lieutenant, United States Navy**

**B.S., Rensselaer Polytechnic Institute, 1989**

**Master of Science in Applied Physics-September 1996**

**Advisors: Robert E. Ball, Department of Aeronautics and Astronautics**

**Gordon E. Schacher, Department of Physics**

The purpose of this thesis is to develop a Survivability and Lethality Assessment Center (SLAC) at the Naval Postgraduate School. Students, faculty, and staff from many different curricula can use the SLAC for thesis research, for validating their own computer codes, and for classroom instruction. The models for the SLAC were obtained from the Survivability/Vulnerability Information Analysis Center (SURVIAC), Teledyne Brown Engineering, Menton, Inc. (for Grumman A/C Systems Advanced Programs), and from the Physics Department at the Naval Postgraduate School.

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Computer Systems in the SLAC include two SUN SPARC-10 Workstations, one Silicon Graphics Indigo, eight VAX6310 terminals with four graphics display consoles, eight IBM compatible computers, and two Macintosh computers. The SLAC now contains 24 models for running simulations. The SLAC is a comprehensive, user-friendly center for individuals or groups that need to use it. The security processing, computer account set-up, and documentation have all been streamlined to facilitate ease of use. Students, faculty, and staff should have no difficulty utilizing the SLAC.

### **AUTONOMOUS FRIENDLY-TARGET IDENTIFICATION AFTER WEAPONS RELEASE**

**Daniel A. Britton-Lieutenant, United States Navy**

**B.S., University of Idaho, 1988**

**Master of Science in Applied Physics-September 1996**

**Advisors: David D. Cleary, Department of Physics**

**Alfred W. Cooper, Department of Physics**

A new method for making friendly missiles avoid friendly targets is presented. Tagging friendly targets with a short range encrypted ultraviolet (UV) signature creates an information "bubble" that is unexploitable over long ranges. Selective photon detectors on missiles create a new identification friend-or-foe (IFF) process. This passive, autonomous IFF capability functions as the missile approaches friendly targets.

The UV signal originates from low pressure mercury lamps configured to radiate a strong, invisible, nearly monochromatic output (254nm). Modulation of optical output results from direct modulation of lamp power supply current. The already low visible emissions can be further suppressed with interference filters. 254nm wavelength light has atmospheric propagation characteristics suitable for this IFF application.

Photon detection is accomplished with solar-blind photomultiplier tubes. Bandpass optical filters block most solar and flame emissions while passing the 254nm modulated ultraviolet signal. Nighttime field tests using a 4.8 watt lamp support the assumed engagement scenario. This scenario analyzes a Mach 4 closure rate with a 30-G missile maneuver underway 2000 feet from the lamp resulting in disabling of proximity detonation and a 200 foot miss distance from the lamp.

### **THERMAL IMAGERY SPECTRAL ANALYSIS**

**Brian Harris Collins-Captain, United States Marine Corps**

**B.S., Rice University, 1990**

**Master of Science in Systems Technology-September 1996**

**Advisor: R. C. Olsen, Department of Physics**

**Second Reader: D. Cleary, Department of Physics**

The first thermal imagery from the Spatially Enhanced Broadband Array Spectrograph System (SEBASS) was analyzed for target detection purposes. Data were acquired during Exercise WESTERN RAINBOW in October of 1995 with Aerospace Corporation's new instrument. SEBASS is a thermal infrared spectral imaging system which collects data in 128 wavelength bands from 7.8 to 13.4  $\mu\text{m}$ . The system has 128 spatial pixels and a ground sample distance of 2.5 feet under the operating conditions of the exercise. The data reduction process included thermal calibration using on-board calibration sources, atmospheric correction through the use of in-scene data, and derivation of thermal emissivity. Analysis of the data was performed using techniques adopted from hyperspectral imagery. The application of the principal components transformation, the spectral angle mapper, and a spectral matched filter showed substantial enhancement of target detection capabilities when compared to the analysis of standard infrared imagery.

## 1996 THESIS ABSTRACTS

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### **BOTTOM BACKSCATTER MAPPING: THE EFFECT OF SECONDARY MULTIPATH INTERACTIONS**

**Erick Brian Cushman-Lieutenant, United States Navy**

**B.S.C.E., Tulane University, 1989**

**Master of Science in Engineering Acoustics-December 1995**

**Master of Science in Physics-December 1995**

**Advisor: Kevin B. Smith, Department of Physics**

It has been shown that good correlation exists between large-scale, high level signal returns of bottom acoustic reverberation and bathymetric ridge structures. The ultimate goal of this type of analysis would be the removal of propagation effects resulting in a large-scale mapping of scattering strengths. Furthermore, analysis with a quasi-CW propagation model suggests a strong correlation between the small-scale fluctuations in the reverberation signal and the bottom acoustic ensonification, thereby suggesting that uncertainties in the predictions of forward propagation may limit the resolution of such mapping. By employing broadband modeling techniques, a valid representation of the complete time domain forward propagation is provided. Diffuse secondary bottom interactions appear to affect the resolution of the primary, direct-path interaction at ranges beyond a few water depths. Analysis of data recorded by near-bottom vertical line arrays (VLA's) confirms the existence of these secondary, multipath interactions in the forward propagation. The exact, two-way travel times from all bottom interactions are modeled and the influence of the secondary interactions is quantified. Possible ramifications for general sonar system performance are discussed.

### **THREE DIMENSIONAL ACOUSTIC EFFECTS IN THE MIDDLE ATLANTIC BIGHT**

**Anthony F. D'Agostino-Lieutenant Commander, United States Navy**

**B.G.S., University of Kansas, 1985**

**Master of Science in Meteorology and Physical Oceanography-June 1996**

**Advisors: Ching-Sang Chiu, Department of Oceanography**

**Kevin B. Smith, Department of Physics**

Under the sponsorship of the Office of Naval Research (ONR) PRIMER program, an integrated acoustic and oceanographic field experiment will be conducted jointly by the Naval Postgraduate School (NPS) and the Woods Hole Oceanographic Institution (WHOI) in the Middle Atlantic Bight (MAB) to study the propagation of sound from the continental slope to the continental shelf. In support of this field study the three-dimensional (3D) effects of the basic mean shelfbreak frontal thermal structure and sloping bathymetry on the planned tomography signal transmissions are modeled using ray methods. Both three-dimensional (3D) and two-dimensional (2D) ray paths and signal arrival structures for an upslope and cross-slope source-receiver geometry are simulated and compared. While the input sound speed field is from a previous summer-time hydrographic section, the input bathymetry is from a recently declassified U.S. Navy DBDB-0.5 data set. Significant 3D environmental effects are found in the modeled cross-slope transmissions, indicating that the physics of horizontal refraction and out-of-the-vertical-plane scattering will be required to properly analyze the acoustic measurements and to construct accurate tomographic maps.

### **THE INFLUENCE OF PHYSICAL SYSTEM PARAMETERS ON THE PERFORMANCE OF ADAPTIVE FILTERS FOR SYSTEM IDENTIFICATION OF MECHANICAL SYSTEMS**

**Michael R. Dargel-Lieutenant, United States Navy**

**B.S.M.E., Norwich University, 1990**

**Master of Science in Engineering Acoustics-September 1996**

**Advisors: Robert M. Keolian, Department of Physics**

**Roberto Cristi, Department of Electrical and Computer Engineering**

Recursive and non-recursive least mean square adaptive filters were used to predict the output of various mechanical systems for a given input. The effects of quality factor (Q), dispersion and transmission time on adaptive filter performance were investigated. Optimal filter delay times and tap weight vector lengths were determined.

## 1996 THESIS ABSTRACTS

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### **CORRELATION OF EXPERIMENTAL AND FINITE ELEMENT MODAL ANALYSIS OF THE PHALANX M61A1 CLOSE-IN WEAPON SYSTEM**

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**B.S., Citadel, 1987**

**Master of Science in Applied Physics-December 1995**

**and**

**Carlos S. Guzman-Lieutenant, United States Navy**

**B.S., Purdue University, 1988**

**Master of Science in Applied Physics-December 1995**

**Advisor: Steven R. Baker, Department of Physics**

The M61A1 galling gun is the principal component of the PHALANX Close-In Weapons System (CIWS), which provides U.S. Navy surface ships with a final defense against anti-ship cruise missiles. The objectives of this study are to provide an experimental set of modal parameters and to validate a new finite-element model (FEM) of the gun. Swept sine frequency response measurements on an actual PHALANX gun were conducted in the laboratory to obtain a complete set of modal parameters (frequency, amplitude, mode shapes). The finite-element model was correlated using the experimental modal frequencies as a reference. This result was obtained by adjusting stiffnesses in the three bearing assemblies within the gun: ball-bearing, needle bearing and ball joint. The investigation was conducted with and without the production muzzle restraint currently used in the fleet. Good agreement between the measured and computed FEM modal parameters was found for the first three modes in both the horizontal and vertical directions for the 5 to 125 Hz frequency range of interest. With the production muzzle restraint installed, agreement between the experimental and finite-element results was poor. It is suspected that "play" in the actual restraint mounting system is present, which is not modeled by the FEM. Recommendations are made for follow-on studies.

### **ANTI-HELICOPTER MINE SYSTEMS**

**Enrique Garcia-Lieutenant, United States Navy**

**B.S., California State University, Los Angeles, 1985**

**Master of Science in Engineering Acoustics-September 1996**

**Advisors: Donald L. Walters, Department of Physics**

**James V. Sanders, Department of Physics**

The development and production of acoustically-cued Anti-Helicopter Mines (AHM) poses a serious threat to low flying helicopters throughout the world. The AHM determines if air approaching helicopter will come within its lethal range. When it does, an IR sensor is energized to provide a firing solution for air explosive charge aimed in the same direction as the IR sensor. The AHM's can perform this mission autonomously using passive sensors only. These features and the relatively low cost of the mines could lead to large scale production and exportation of AHM's. This thesis explores this concept with an emphasis on the acoustic principles applied to make these mines effective. The results from an AHM proof of concept evaluation conducted by Sandia National Laboratories in 1993 are studied to validate the operational capabilities of AHM systems. The results proved that AHM systems are effective and require serious consideration in future deployments of helicopters in hostile environment.

## 1996 THESIS ABSTRACTS

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### **AN EXPERIMENTAL COMPARISON OF A PIN STACK TO A CONVENTIONAL STACK IN A THERMOACOUSTIC PRIME MOVER**

**Rodney Jay Gibson-Lieutenant, United States Navy**

**B.S., Montana College of Mineral Science and Technology, 1987**

**Master of Science in Applied Physics-June 1996**

**Advisors: Robert M. Keolian, Department of Physics**

**Thomas J. Hoffer, Department of Physics**

This thesis is an experimental comparison of a pin stack to a conventional rolled stack in a thermoacoustic prime mover. A thermoacoustic prime mover is a type of natural heat engine which converts a temperature gradient across a stack into acoustic energy. A pin stack uses wires which are arranged in a hexagonal array instead of the parallel or rolled plates of a conventional stack. The pin stack was constructed by threading 75 micron constantan wire between the hot and cold heat exchangers 2312 times. Computer modeling with the program DeltaE predicts that a pin stack will significantly improve the efficiency of the prime mover. In the experiment the temperature gradient across the stack was supplied by submerging the cold end in liquid nitrogen while holding the hot end at ambient temperature. The experiment was conducted for both the pin stack and a conventional rolled stack. The pin stack produced 20% higher acoustic pressures than the rolled stack and the efficiency was up to 31% better. The pin stack went into onset at a 41% lower mean pressure than the rolled stack.

### **DEVELOPMENT AND VALIDATION OF A SECOND GENERATION VISIBILITY-BASED MODEL FOR PREDICTING SUBJECTIVE AND OBJECTIVE MINIMUM RESOLVABLE TEMPERATURE DIFFERENCE PERFORMANCE FOR STARING THERMAL IMAGING SYSTEMS**

**Michael S. Groen-Captain, United States Marine Corps**

**B.S., Calvin College, 1986**

**Master of Science in Applied Physics-December 1995**

**Master of Science in Electrical Engineering-December 1995**

**Advisors: Alfred W. Cooper, Department of Physics**

**Ron J. Pieper, Department of Electrical and Computer Engineering**

Several models have been proposed to predict the minimum resolvable temperature difference (MRTD) performance of second generation thermal imaging systems (TIS) which incorporate staring focal plane arrays. It has been suggested that these models are not accurate for predicting the performance of second generation staring focal plane arrays which have severe phasing or sampling characteristics not amenable to linear modulation transfer function analysis. A second problem with these models is that they require a particular set of assumptions concerning the observer eye/brain recognition process, which limits their usefulness in the prediction of the performance for systems that incorporate automatic target recognition (ATR) devices. In this thesis, a new model is presented for predicting the MRTD performance of second generation thermal imagers based on a minimum threshold input contrast, and a contrast reduction factor due to aliasing and blurring effects. The model makes no assumptions regarding the recognition process, which allows a separate threshold value to be defined for either a human or machine observer. The model incorporates aliasing concepts, and extends performance prediction beyond the nominal Nyquist rate of the system. The model's predictions are compared to the predictions of the current standard FLIR92 model and measured laboratory results for two different staring focal plane array imagers. In both cases, the model's predictions match measured results more closely than the predictions of FLIR92.



## 1996 THESIS ABSTRACTS

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### **DESIGN AND EVALUATION OF MINE AND UXO DETECTORS TO AUTONOMOUS MOBILE ROBOTS**

**Curtis J. Goodnight-Lieutenant, United States Navy**

**B.S., Naval Postgraduate School, 1996**

**Master of Science in Electrical Engineering-September 1996**

**Advisors: Xiaoping Yun, Department of Electrical and Computer Engineering**

**David Cleary, Department of Physics**

The study focuses on the development of a light weight detector to be used for the purpose of mine / Unexploded Ordnance (UXO) detection. The detector was developed based upon a twin oscillator design, and the performance of this design was tested with respect to diameter of the sensing coil, operating frequency, and the number of turns of the sensing coil. The results of this study provide a field tunable, light weight, low power mine / UXO detector with significant range. The ability to equip a robot with this device and send it into the field will prove to be an invaluable asset to ongoing mine sweeping operations.

### **DESIGN, DEVELOPMENT AND TESTING OF THE ALL-REFLECTION MICHELSON INTERFEROMETER FOR USE IN THE MID-ULTRAVIOLET REGION**

**Jeffrey D. Hicks-Lieutenant, United States Navy**

**B.S., Auburn University Auburn, Alabama, 1988**

**Master of Science in Astronautical Engineering-December, 1995**

**Master of Science in Applied Physics-December, 1995**

**Advisor: D.D. Cleary, Department of Physics Department**

The development of the Naval Postgraduate School's high resolution All-Reflection Michelson Interferometer has progressed into the mid-ultraviolet region. Two separate Mercury light sources, a pen-ray lamp and a germicidal lamp, were used to evaluate the performance of the instrument for the 2537 Å emission. The interferometer uses a pinhole aperture at the focus of an off-axis parabolic mirror to obtain a collimated input beam. A plane sinusoidal diffraction grating divides the beam into two orders. Planar mirrors reflect the beams back to the grating where they are diffracted again such that both beams are now in the plane of the detector. The beams recombine to form a linear interference pattern which is recorded by an ultraviolet detector. Data-reduction software coherently adds the interference pattern matrix and creates a doubled-sided interferogram. The spectrum is obtained by using Fourier Transform techniques. This compact, lightweight and economically produced interferometer has no moving parts. For this reason, the All-Reflection Michelson Interferometer is well suited for remote sensing of mid- to extreme-ultraviolet ionospheric emissions from a sounding rocket, space shuttle or satellite platform.

### **EXPERIMENTAL INVESTIGATION OF A HIGH RESOLUTION SONAR**

**Lim Chin Huat-Major, Republic of Singapore Navy**

**B.Sc., National University of Singapore, March 1985**

**MBA, National University of Singapore, September 1995**

**Master of Science in Physics-March 1996**

**Advisor: Donald L. Walters, Department of Physics**

This thesis investigated a laboratory synthetic aperture sonar designed to test the algorithms and techniques needed to detect, classify and identify mine-like objects. Previous synthetic aperture sonar work at NPS achieved 5 cm range resolution and 1 cm azimuth resolution. This thesis developed a pulsed, frequency modulated, synthetic aperture sonar that achieved range and azimuth resolutions of about 1 cm. The processed images clearly reveal detection of targets with a high degree of certainty. However, the ability to classify and identify mines and rocks is less certain because of speckle and glint effects. The high resolution algorithms improved the detection and overall image quality of targets, and achieved a signal to noise ratio of 35 dB. The 2:1 frequency spread of the FM chirp increased the signal to noise ratio by 20 dB compared to an unfocused synthetic aperture system. However, a significant finding is that resolution

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alone is not sufficient to classify and identify mine-like targets in complex backgrounds. Resolution of this problem will require a different approach such as utilizing adaptive acoustic daylight to avoid the speckle and glint problems inherent with coherent illumination. To achieve a classification and identification capability, a completely different approach to acoustic illumination and signal processing is needed.

### **OPTICAL MODULATOR LM0202 P CHARACTERISTICS: APPLICATION TO AMPLITUDE MODULATION OF ARGON-ION LASER**

**Michael C. Ladner-Lieutenant, United States Navy**

**B.S., United States Naval Academy, 1989**

**Master of Science in Physics-June 1996**

**Advisors: S. Gnanalingam, Department of Physics**

**Andres Larraza, Department of Physics**

The purpose of this thesis is to examine the possibility of using a commercial electro-optic modulator, the LM 0202 P modulator manufactured by Gsanger OptoElektroniks of Germany, to provide an amplitude modulated light source to test a theory of the conversion of amplitude to frequency modulation of light in fiber optics. The main focus of this thesis is to experimentally determine the performance characteristics of the modulator including the frequency response in the frequency range 1 kHz to 150 MHz. The effects of inductive loops, both external and internal to the modulator, are examined and solutions discussed. Amplitude modulation of an Argon-Ion Laser operating at 514.5 nm at twenty-five percent modulation at 125 MHz has been achieved.

### **AEROTHERMAL EFFECTS ON THE INFRARED SEEKER STARING SENSOR PERFORMANCE OF HIGH SUPERSONIC MISSILES**

**Clélio Dinis Ferreira Leite-Lieutenant, Portuguese Navy**

**B.S., Portuguese Naval Academy, 1987**

**Master of Science in Applied Physics-December 1995**

**Advisor: Alfred W. Cooper, Department of Physics**

The present work investigates the aerothermal effects on the electro-optical performance of a conceptual infrared seeker missile at Mach 4 at small angles of attack. Two window dome configurations are studied: an optical hemisphere and ellipsoidal shape window attached to a 3:1 ogive nose. A three dimensional thin-layer compressible flow solver is used to compute the flow field in front of the window and the window aerodynamic heating. A solution adaptive-grid scheme is applied to accurately compute the flow field and capture the bow shock. Noise-Equivalent-Temperature-Difference degradation due to "background" noise of the hot window is derived and computed for 3 levels of array non-uniformity for a range of mean dome temperatures covering the whole supersonic regime. Acquisition range for a staring sensor is estimated for several maritime scenarios modeled by LOWTRAN code. Background photon flux distribution on an array generated by the hot dome is computed using radiation transfer methods using the dome temperature field obtained by computational fluid dynamic methods. It is found that array non-uniformity has a strong influence on the seeker performance. This study indicates that the non-uniformity of the dome temperature has significant influence on the array fixed pattern noise induced by dome emission and so in the seeker detection and tracking ability.



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### **EVALUATION OF EFFECTIVE MDTD/MRTD FOR FLIR FROM PREOS92 MEASUREMENT DATA**

**Fu-Chau Liu-Captain, Republic of China Army**  
**B.S., Chung-Cheng Institute of Technology, 1988**  
**Master of Science in Applied Physics-June 1996**  
**Advisors: Alfred W. Cooper, Department of Physics**  
**Donald L. Walters, Department of Physics**

This thesis addresses the evaluation of the apparent target-background temperature difference ( $\Delta T_{app}$ ) at maximum range and compares  $\Delta T_{app}$  with MDTD/MRTD of a typical FLIR system. The atmospheric propagation code (SEARAD) and Planck's radiation law were employed to obtain atmospheric transmittance and path radiance. The atmospheric parameters were selected as close to the aircraft overflights as possible using PREOS 92 data as inputs of the SEARAD code. Ship target (R/V POINT SUR) modeling was established for MDTD/MRTD evaluation using a rectangular parallelepiped model of the ship's physical length, width and height. The geometry data for MDTD/MRTD evaluations were also selected from the PREOS 92 experiment measurement set. The MDTD/MRTD functions for a generic FLIR in wide field of view (WFOV) application were deduced from Shumaker. Johnson criterion was employed as a detection criterion. Resolution line-pairs at detection range to resolve the target have also been evaluated and compared against Johnson Criterion.

The temperature differences between  $\Delta T_{app}$  and MDTD at detection range show large scatter, ranging from 5% to 600 %. They also show agreement with the same sensor altitude and viewing angle. A comparison of  $\Delta T_{app}$  with MRTD at classification range and identification range show that using NFOV would be more appropriate for target classification/recognition. Resolution line-pairs at detection range derived from a typical WFOV MRTD curve show 10%~50% error for the eight runs, which is acceptable as compared against Johnson Criterion quoted as  $1 \pm 0.25$  mRad.

### **THE VULNERABILITY OF AN AIRBORNE EARLY WARNING (AEW) SYSTEM AGAINST STAND-OFF NOISE JAMMING (SOJ)**

**Chih-Cheng Lo-Lieutenant Colonel, Republic of China Air Force**  
**B.S., Air Force Academy, 1978**  
**Master of Science in Applied Physics-June 1996**  
**Advisors: D.C. Schleher, Information Warfare Academic Group**  
**James V. Sanders, Department of Physics**

Based on the lessons learned from the Falkland War, an airborne early warning (AEW) system's importance is fully appreciated, and many countries field the AEW system to be a force multiplier for their air defense system. In this thesis, the AEW system's vulnerability, the sensitivity of each factor dominating the AEW system's detection range under hostile jamming, and the effect of stand-off noise jamming (SOJ) impacting the AEW system's detection range are evaluated using a simulation model to explore the AEW system's susceptibility and detection range degradation in a realistic combat environment.

### **LIMIT-CYCLE BEHAVIOR IN FREE ELECTRON LASERS**

**R. M. Mabe-Lieutenant Commander, United States Navy**  
**B.S., North Carolina State University, 1982**  
**Master of Science in Physics-December 1995**  
**Advisor: Robert L. Armstead, Department of Physics**

Many Free Electron Lasers (FEL) are driven by short electron pulses which create equally short optical pulses. At saturation, the strong optical fields present in the undulator result in the trapped-particle instability which drives the carrier wave unstable and modulates the optical pulse. The trapped-particle instability coupled with the short optical pulses can result in periodic oscillations of the pulse shape. This results in oscillations of the output power even though all input parameters are constant. The effect is known as limit-cycle behavior.

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The character of the oscillation is highly nonlinear and is dependent on the physical input parameters of the current density, resonator losses, electron pulse length and desynchronism of the resonator cavity. These power oscillations affect the operation of the FEL, requiring better insight into their cause and control. Using simulations based on a self consistent Maxwell-Lorentz theory of FEL operation, the dependence of the limit-cycle oscillations on these physical parameters is examined.

### **TRANSIENT PHENOMENA IN THERMOACOUSTIC PRIME MOVERS**

**Ching-Kai Meng-Lieutenant Commander, Republic of China Navy**

**B.S., Chinese Naval Academy, 1985**

**Master of Science in Engineering Acoustics-June 1996**

**Advisors: Anthony A. Atchley, Department of Physics**

**Robert M. Keolian, Department of Physics**

The purpose of this thesis is to investigate the evolution of the acoustic pressure waveform and temperature change across the heat exchangers as functions of time in a thermoacoustic prime mover. Measurements are reported for both nitrogen and helium gas under different mean pressures and initial temperature differences. Aspects of this thesis included the design and construction of the prime mover and implementation of a computer controlled data acquisition system. The goal is to form a set of data with which to test transient, nonlinear theories of thermoacoustics. The main conclusion is that models will have to take into account the performance of heat exchangers to accurately model the initial build up of the oscillations.

### **HIGH-RESOLUTION RESIDUE ANTENNA ARCHITECTURES FOR WIDEBAND DIRECTION FINDING**

**Luis E. Rodrigues Moita-Lieutenant, Portuguese Navy**

**B.S., Portuguese Naval Academy, 1989**

**Master of Science in Applied Physics-June 1996**

**Advisors: Phillip E. Pace, Department of Electrical and Computer Engineering**

**Robert M. Keolian, Department of Physics**

The performance of two novel interferometer antenna architectures for high-resolution, wideband direction finding are investigated. The first configuration incorporates a Symmetrical Number System (SNS) encoding of the interferometer amplitude response (symmetrical folding waveform). The second configuration incorporates a Residue Number System (RNS) encoding of the interferometer phase response (saw-tooth waveform). The residue architectures serve as a source for resolution enhancement in an interferometer array by decomposing the analog spatial filtering operation into a number of parallel sub-operations (moduli) that are of smaller computational complexity. Each sub-operation only requires a precision in accordance with the size of the modulus. A much higher resolution is achieved after the  $N$  moduli are used and the results of these low precision sub-operations are recombined. A four-element, 3 channel array using moduli set  $m_1 = 3$ ,  $m_2 = 4$  and  $m_3 = 5$  was constructed in a ground plane using rectangular waveguide elements with a center frequency of 8.5 GHz. Experimental results are compared with the simulation results to demonstrate the advantages of this approach. The frequency response of the RNS array is investigated numerically. To correct the quantization errors due to any frequency offset, a fast correction algorithm is derived and is shown to have excellent results over a wide bandwidth.

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### **DETECTION OF MINES USING HYPERSPECTRAL ANALYSIS**

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**Master of Science in Applied Physics-June 1996**

**Advisors: David D. Cleary, Department of Physics.**

**Suntharalingam Gnanalingam, Department of Physics**

This study focuses on the development of computer algorithms that can be used for automatic mine detection using hyperspectral imagery. These algorithms perform a pixel-by-pixel comparison of the scene spectra with the spectrum of a mine. The goal is to assign to every pixel a scale factor which gives the relative probability of finding a mine. Algorithms were tested on simulated data taken from the NPS Middle Ultraviolet Spectrograph (MUSTANG). Three computer methods are tested and relative results were compared. This analysis suggests that the potential exists to use these methods in military applications. The ability to identify features in an image based solely on their spectral signature provides a new dimension to imagery interpretation.

### **SIMULATION OF DOUBLE BARRIER RESONANT TUNNELING DIODES**

**Roy M. Porter-Lieutenant, United States Navy**

**B.S., Pennsylvania State University, 1988**

**Master of Science in Applied Physics-June 1996**

**Advisors: James Luscombe, Department of Physics**

**David Cleary, Department of Physics**

The double barrier resonant tunneling diode (DBRTD) is one of several devices currently being considered by the semiconductor industry as a replacement for conventional very large scale integrated (VLSI) circuit technology when the latter reaches its currently perceived scaling limits. The DBRTD was one of the first and remains one of the most promising devices to exhibit a room temperature negative differential resistance (NDR); this nonlinear device characteristic has innovative circuit applications that will enable further downsizing. Due to the expense of fabricating such devices, however, it is necessary to extensively model them prior to fabrication and testing. Two techniques for modeling these devices are discussed, the Thomas-Fermi and Poisson-Schroedinger theories. The two techniques are then compared using a model currently under development by Texas Instruments, Incorporated.

### **ATMOSPHERIC PROPAGATION SIMULATIONS AND BOEING'S HIGH AVERAGE POWER FREE ELECTRON LASER**

**Luis Ramos-Lieutenant, United States Navy**

**B. S., United States Naval Academy, 1989**

**Master of Science in Applied Physics-December 1995**

**Advisor: William Colson, Department of Physics**

The development of a high average power FEL for military applications, whether shipboard or not, represents a significant advancement in technology over present weapon systems design. The FEL has significant advantages over conventional kinetic systems and other classical high-energy laser systems. The rapid response, wavelength tunability, and infinite magazine make the FEL a highly desirable shipboard weapon system.

The initial part of this thesis examines the advantages of a FEL over a conventional kinetic weapon. Section II explores the atmospheric phenomena that affect the propagation of a laser beam enroute to its target. Section III presents the Boeing FEL proposal followed by the theory of the FEL. Last, in Sections V and VI, simulations are conducted to analyze the FEL's feasibility.

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### OPTICAL SYSTEM EVALUATION

**Carlos Renato Campos Rangel-Lieutenant Commander, Brazilian Navy**

**B.S., Brazilian Naval Academy, 1983**

**Master of Science in Applied Physics-December 1995**

**Advisor: David Scott Davis, Department of Physics**

Optical and infrared sensors have an important role to play in modern military engagements, as the deployment of passive systems increases. To guarantee the efficient development and usage of such equipment, at a reasonable cost, a reliable and realistic simulation of sensor performance is fundamental. The research project presented in this thesis consists of two parts. First, basic software modules that characterize the target-detector radiative transfer problem were developed. This was accomplished by developing separate modules for each physical aspect of the problem. The second part concerned the viability of implementing the physics of such real-world radiative transfer effects into existing military simulation tools. The chosen simulation environment for this thesis was *NPS Platform Foundation*, an existing simulation software package that was developed at the Naval Postgraduate School.

### MEASUREMENTS WITH WIRE MESH STACKS IN THERMOACOUSTIC PRIME MOVERS

**Mark S. Reed-Lieutenant Commander, United States Navy**

**B.A., Shippensburg State College, 1982**

**Master of Science in Applied Physics-June 1996**

**Advisors: Thomas J. Hoffer, Department of Physics**

**Anthony A. Atchley, Department of Physics**

This thesis documents the first measurements of a thermoacoustic prime mover using wire mesh screens as the stack material. A thermoacoustic prime mover is a heat engine which converts thermal energy to sound. The stack material is sandwiched between the hot and cold heat exchanger and exchanges heat with the cycling gas elements flowing in the stack. The experimental stacks were constructed by inserting disks cut from wire mesh in a tube. In addition to simplicity, these stacks have two significant advantages. First, the wire is relatively impervious to moderately high temperatures and second, the effective thermal conductance of the structure is one to two orders of magnitude lower than a comparable metal "parallel plate" structure. Since no linear theoretical thermoacoustic models exist for these wire mesh stacks, the approach taken was simply to measure the performance of several different mesh stacks. Results gathered from two different prime movers indicate acoustic onset temperatures and amplitude performance comparable to the best data for parallel plate stacks. Moreover, measured efficiencies for mesh stacks appear to be substantially higher than for parallel plates.

### VIBRATION MEASUREMENTS ON THE PHALANX ELECTRO-OPTICAL STABILIZATION SYSTEM

**James E. Schmidt-Lieutenant Commander, United States Navy**

**B.A., John Carroll University, 1985**

**Master of Science in Engineering Acoustics-September 1996**

**Advisor: Steven R. Baker, Department of Physics**

**Second Reader: Robert M. Keolian, Department of Physics**

The installation of the new PHALANX Surface Mode (PSUM) upgrade will enable the PHALANX to handle a wider range of threats, such as a small boat approaching the ship. The objective of the research described in this thesis was to measure the vibration of a prototype forward looking infrared (FLIR) camera stabilizer system during live-fire tests to evaluate its performance. Uniaxial, triaxial, and angular accelerometers were mounted at 19 different locations on the stabilizer and on the camera. Acceleration data were collected during eight live fire tests conducted at a Navy range, and the results analyzed. The power spectral densities (PSD) of the input linear accelerations at key locations on the stabilizer were calculated. The azimuth and elevation angular displacements of the FLIR camera mount were also

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calculated. The azimuth and elevation angular displacement of the plane of the stabilizer pedestal mounting points were also calculated. Recommendations are made for follow-on studies.

### **QUANTITATIVE EVALUATION OF THE LIMITATIONS OF THE RADIATION BOUNDARY ELEMENTS IN THE FINITE ELEMENT CODE ATILA**

**Panagiotis A. Sinanoglou-Lieutenant, Hellenic Navy**

**B.S., Hellenic Naval Academy, 1985**

**Master of Science in Applied Physics-June 1996**

**Advisors: Steven R. Baker, Department of Physics**

**Clyde L. Scandrett, Department of Mathematics**

A quantitative evaluation of the limitations of the radiation boundary elements in the finite element code ATILA [Ref. 1] has been performed. Five three-dimensional models were employed, each representing a rigid spherical solid surrounded by water. Monopolar, dipolar and quadrupolar incident spherical waves were introduced and the corresponding scattered waves were computed using the ATILA code and an exact analytical solution.

The dimensionless parameters that characterize the problem are  $ka$ ,  $kL$ , and  $kR$  where  $k$  is the wavenumber of sound in water,  $a$  is the radius of the scatterer,  $R$  is the outer fluid mesh radius, and  $L$  is the thickness of the fluid layer. The range of values investigated were  $kR=1.5, 2.5, 4.0$ ,  $ka=0.5, 1.0, 2.0$  and  $kL=0.5, 1.0$ .

For axially symmetric incident fields, the maximum normalized errors occurred at the poles and were 9%, 12%, and 6%, respectively. Furthermore, the errors for monopolar and dipolar incident fields were strongly influenced by the location of the radiation boundary ( $kR$ ), less so by the scatterer's radius ( $ka$ ); specifically, the error decreases with increasing  $kR$  and/or  $ka$ . The errors for quadrupolar incident fields do not exhibit any significant dependence on  $kR$  or  $ka$ . The errors for all the axially symmetric incident fields were not affected by variations of the element's size ( $kL$ ). For non-axially symmetric incident fields, the maximum deviation occurred at the equatorial points and was less than 5.5%.

Further investigation using a two-dimensional model is proposed in order to determine the range of values of  $ka$ ,  $kL$ , and  $kR$  which will result in negligibly small errors.

### **STEP FREQUENCY WAVEFORM DESIGN AND ANALYSIS USING THE AMBIGUITY FUNCTION**

**Paulo A. Soares-Lieutenant, Portuguese Navy**

**B.S., Portuguese Naval Academy, 1989**

**Master of Science in Applied Physics-June 1996**

**Advisors: Gurnam Gill, Department of Electrical and Computer Engineering**

**Suntharalingam Gnanalingam, Department of Physics**

This thesis investigates the use of the step frequency waveform, its design and analysis using the ambiguity function. The step frequency waveform consists of a series of  $N$  pulses each with a pulse width of  $\tau$ , and whose frequency is increased from pulse to pulse in steps of  $\Delta f$ . A design procedure for detection of small targets with a surface (land or sea) based step frequency radar employing a high pulse repetition frequency (PRF) waveform is developed. The proposed method determines the waveform parameters for given radar specifications. A simple graphical implementation as well as a computer implementation are presented. The theoretical dimensions of the step frequency waveform are defined and verified for some waveforms with parameters similar to the waveform of interest. Finally, the ambiguity function is used to analyze the step frequency waveform.

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### **HIGH ORDER PARAMETRIC X-RADIATION FROM SILICON AND LITHIUM FLUORIDE CRYSTAL MONOCHROMATORS**

**Joseph Raymond Thien-Lieutenant, United States Navy**

**B.S., United States Naval Academy, 1984**

**Master of Science in Physics-December 1995**

**Advisor: Xavier K. Maruyama, Department of Physics**

This thesis examines parametric x-radiation (PXR) generated by Silicon and Lithium Fluoride monochromators, including the first observation of PXR from Lithium Fluoride. Parametric x-radiation may be described as the Bragg scattering of virtual photons associated with relativistic electrons as they pass through single crystal monochromators. As the photons interact with the crystal lattice they produce x-rays which meet the Bragg condition  $n\lambda = 2d\sin q_b$ , where  $q_b$  is the angle between the electron beam and the crystal plane. PXR data were collected from Silicon and Lithium Fluoride crystals using a SiLi detector. The locations of the energy peaks are compared to the locations predicted by theory and the intensity ratios between the peaks are also compared to the theoretical ratios. The PXR energy observed was as predicted by theory for Silicon and Lithium Fluoride monochromators. The observed peak intensity ratios for Silicon were not in agreement with intensity ratios predicted by theory. Intensity ratios observed from Lithium Fluoride were in agreement with the predicted value.

### **HIGH SPEED NUMERICAL INTEGRATION OF FERMI DIRAC INTEGRALS**

**Jeremy Stewart Thompson-Lieutenant, United States Navy**

**B.S., United States Naval Academy, 1988**

**Master of Science in Physics-June 1996**

**Advisors: James H. Luscombe, Department of Physics**

**Donald Lee Walters, Department of Physics**

In this thesis we present an algorithm for the precise determination of Fermi-Dirac (FD) integral functions,  $f_t(h)$ , for arbitrary values of the parameter  $t$  and the argument  $h$ . The FD integrals are a class of functions that are used extensively in the modeling of semiconductor devices, e.g., when the charge carriers are in a strongly quantum, degenerate regime, such as in heavily doped semiconductors. The determination of FD integrals has a long history. Our approach to evaluating these functions is two-fold. First, we develop exact power series expansions of the integral. These series, however, converge too slowly to be a practical means of evaluating the integral. The second aspect of our approach is to apply numerical series acceleration methods to improve significantly the rate of convergence of these series expansions. The result is a computer program that provides efficient, accurate values of the FD integral.

### **OPTICAL CHARACTERISTICS OF LEXEL 85 ARGON ION LASER AND GSANGER LM0202P MODULATOR: APPLICATION TO AM-FM LIGHT CONVERSION**

**Harlan V. Wallace-Lieutenant, United States Coast Guard**

**B.S., University of Utah, 1989**

**Master of Science in Physics-June 1996**

**Advisors: D. Scott Davis, Department of Physics**

**Andres Larraza, Department of Physics**

The purpose of this thesis is to examine the possibility of using a commercial electro-optical modulator, the LM0202P modulator, manufactured by Gsanger Opto-Elektronik of Germany, to amplitude modulate an argon ion laser, the LEXEL model 85, for proving a theory of the conversion of amplitude to frequency modulation of light in fiber optics. The main focus is to analyze the spectral output of the laser both before and after being directed through the modulator. Also to be considered is launching the laser light down a length of optical fiber. It was determined that the laser does not produce a single mode, monochromatic spectral line. Further, it was determined that when the laser is directed through the modulator, the structure on the laser profile tends to blur. This effect increases when DC bias voltage is applied to the modulator. Additionally, when the modulator is driven with an AC modulation superimposed on the DC



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bias voltage, the resultant optical spectral profile does not correspond to that expected for sinusoidal amplitude modulation.

### **NPS HIGH RESOLUTION SYNTHETIC APERTURE SONAR**

**Joseph Donald Welter-Lieutenant Commander, United States Navy**

**B.S.E.E., United States Naval Academy, 1982**

**Master of Science in Electrical Engineering-December 1995**

**Master of Science in Applied Physics-December 1995**

**Advisors: Donald Walters, Department of Physics**

**Roberto Cristi, Department of Electrical and Computer Engineering**

This thesis investigated the use of synthetic aperture techniques to achieve a long effective aperture, high resolution, imaging sonar. The approach included a full simulation of the system using the MATLAB programming environment that provided a model for developing six data processing algorithms and a working 25KHz, 1 m baseline, air medium synthetic aperture sonar. The six azimuthal processing techniques included: 1) a normal, real aperture, 2) an unfocused synthetic aperture, 3) a hybrid focused-unfocused system, 4) a fully focused one line algorithm, 5) a limited two-dimensional, fully focused algorithm and, 6) a limited two-dimensional, hybrid focused-unfocused algorithm. This thesis compared the run times, resolutions, and signal to noise ratios achieved by the six techniques both in simulation and experimental measurements collected with the actual prototype.

### **THE THREAT OF RADIOLOGICAL TERRORISM**

**Matthew E. Woods, Lieutenant, United States Navy**

**B.S., United States Naval Academy, 1990**

**Master of Arts in National Security Affairs-September 1996**

**Advisor: Peter R. Lavoy, Department of National Security Affairs**

**Second Reader: Terry Johnson, Department of National Security Affairs**

**Second Reader: Xavier Maruyama, Department of Physics**

WMD terrorism is a new concern. The United States is preparing for the possibility of terrorist acts involving chemical, biological, and nuclear weapons, but the scope of these preparations is too narrow. This thesis argues that radiological devices are also viable weapons of mass destruction for terrorism. Radiological weapons are not nuclear explosives, they are designed to disperse radioactive material over an area by mechanical means or conventional explosives. The potential for radiological terrorism depends upon access to the required nuclear materials and the motivations for terrorists to use radiological weapons. Radiological weapons can use non-weapons grade nuclear material which is widely accessible throughout the world. The material is under a spectrum of physical security systems with little accountability and verification. Radiological weapons can further terrorist objectives because they can be used to contaminate individuals without producing the immediate and widespread catastrophic damage normally associated with WMD. This prospect of contamination is enough to incite the public's fear of the nuclear unknown or nuclear phobia. To counter radiological terrorism, the U.S. government should expand indications and warning through efforts to maximize the intelligence community's human intelligence assets and exploit open source collection.

## 1996 THESIS ABSTRACTS

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### **EFFECTS OF SHALLOW WATER BOTTOM INTERFACE ROUGHNESS AND VOLUME FLUCTUATIONS ON BROADBAND PULSE RESOLUTION**

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**B.S., Chung Cheng Institute of Technology, 1987**

**Master of Science in Engineering Acoustics-June 1996**

**Advisor: Kevin B. Smith, Department of Physics**

**Second Reader: Anthony A. Atchley, Department of Physics**

Typical acoustic propagation in shallow water environments is dominated by bottom-interacting paths. The effects of rough bottom interfaces and sediment volume fluctuations are investigated using model simulations. A numerical study of low-frequency (~200 Hz) broadband pulse propagation is presented and several characterizations of bottom factors are examined. In particular, the variations of the interface rms roughness and a volume fluctuation strength constant on the time resolution of the broadband pulse are investigated. It is shown that interface roughness is the dominant factor in the degradation of pulse resolution.



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